Teaching and Assessing Cognitive Competencies in Plastic Surgery – within the context of competency based medical education

Becher Alhalabi, BMedSc, BMBCh, MHPE

Department of Experimental Surgery

McGill University, Montreal, Quebec

April 2020

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy

Abstract: Postgraduate surgical education is evolving into a competency-based model requiring a similar change in the educational methods used. Technical skills have been the focus of surgical training to date, but challenging educators is the teaching of non-technical skills (Cognitive Competencies). Breast augmentation is the most commonly practiced aesthetic surgical procedure in the United States but constitutes little training due to low exposure and participation. This results in low confidence among residents, despite introducing multiple interventions, for instance, residents-run aesthetic clinics and dedicated aesthetics rotations. An understanding of current tools used in training in plastic surgery and what constitutes cognitive competence among expert surgeons will allow for the development of interventions that target such competencies. A systematic review of the literature in plastic surgery displayed limited involvement of competency assessment and the need for focus on teaching and assessing of the cognitive domain. A commonly employed model is resident-run clinics, the study of which will help optimize their use and integration into competency-based training. Using breast augmentation as a model surgery, experts were interviewed to analyze mental processes involved in aesthetic procedures and to develop a framework for teaching and assessing cognitive competencies in plastic surgery. A curriculum was then developed to teach cognitive competencies in Breast Augmentation and a novel method was used to assess these competencies. A self-controlled trial was designed to compare exposure to the designed curriculum on cognitive competencies among learners of different levels. This demonstrated the ability to transfer cognitive skills and test them and acts as a primer for the development of further competency-based models in plastic surgery. Moreover, given the importance of marking in plastic surgery, studying the interplay between cognitive competencies, marking, perception and planning is essential. A trial was designed to study the effect of the designed curriculum on the learner's ability to mark and plan for breast augmentation surgery. These results introduce cognitive competencies within the field of plastic surgery and provide a model for teaching and assessing these competencies in Plastic Surgery. Future research should aim to show the effectiveness of such interventions on self-confidence and emotional regulation, clinical performance, complications and patient satisfaction.

Résumé:

L'enseignement de la chirurgie postuniversitaire évolue vers un modèle basé sur les compétences ce qui demande un changement similaire dans les méthodes pédagogiques utilisées. Les compétences techniques ont été, jusqu'à ce jour, au centre de la formation en chirurgie, mais les éducateurs ont de la difficulté avec l'enseignement d'autres compétences non techniques (les compétences cognitives). L'augmentation mammaire est l'intervention chirurgicale esthétique la plus couramment pratiquée aux États-Unis, mais constitue une petite portion de la formation, ainsi que d'autres chirurgies esthétiques. Il en résulte un manque de confiance de la part des résidents, en dépit de l'introduction de multiples interventions, par exemple, les cliniques esthétiques prises en charge par les résidents et les rotations dédiées à la chirurgie esthétique. Une bonne compréhension des outils actuels utilisés dans la formation en chirurgie plastique et de la compétence cognitive chez les chirurgiens experts permettra le développement d'interventions qui ciblent ces compétences. Une revue systématique de la littérature en chirurgie plastique indique une évaluation des compétences des résidents limitée et la nécessité de se concentrer sur l'enseignement et l'évaluation du domaine cognitif. Un modèle couramment utilisé est celui des cliniques dirigées par des résidents, dont l'étude permettra d'optimiser leur utilisation et leur intégration dans la formation axée sur les compétences. En prenant l'augmentation mammaire comme chirurgie modèle, des experts ont été interviewés pour analyser les processus mentaux impliqués dans les procédures esthétiques et élaborer un cadre pour l'enseignement et l'évaluation des compétences cognitives en chirurgie plastique. Un programme a ensuite été développé pour enseigner les compétences cognitives en augmentation mammaire et une nouvelle méthode a été utilisée pour évaluer ces compétences. Un essai autocontrôlé a été conçu pour tester ce programme. Celui-ci a démontré la capacité de transférer des compétences cognitives et de les tester, et peut servir de base pour le développement de nouveaux modèles basés sur les compétences. De plus, étant donné l'importance du marquage en chirurgie plastique, l'étude de l'interaction entre les compétences cognitives, le marquage, la perception et la planification est essentielle. Un essai a été conçu pour étudier l'effet du programme sur la capacité de l'apprenant à noter et à planifier la chirurgie d'augmentation mammaire. Ces résultats introduisent des compétences cognitives en chirurgie plastique et fournissent un modèle d'enseignement et d'évaluation de ces compétences. Les recherches futures devraient viser à montrer l'efficacité de ces interventions sur la confiance en soi, la régulation émotionnelle, performance clinique, les complications et la satisfaction des patients.

Acknowledgements

This work was generously supported by an Association for Surgical Education (ASE) / Plastic Surgery Foundation (PSF) combined research grant awarded by the Plastic Surgery Foundation.

I would like to thank my advisory committee for their support and guidance and most importantly my supervisors, Dr. Mirko Gilardino, and Dr. Melina Vassiliou. Moreover, the participation of the subject matter experts and participants who took part in the interview process and helped by providing testing and feedback is much appreciated. Lastly, I would like to thank the members of the Henry K.M. de Kuyper Education Centre at the Montreal General Hospital for their support and understanding, especially, Dr. Yusuke Watanabe, Dr. Amin Madani, and Dr. Elif Bilgic for their contribution to this work, as well as the Steinberg-Bernstein center for minimally invasive surgery lab members.

I owe gratitude to my clinical mentors whose support and understanding allowed me to reach this level and who groomed me with the skills to care for others, the judgement to do so safely and the heart to do it with compassion.

I also owe thanks to my colleagues, previous senior residents and upcoming juniors who were there for me in my good and bad times, guided me, and provided a listening ear.

My family who raised me to become the person I am and always been there for me are who I dedicate this 6-year journey to, my parents Houda and Taleb and my brothers Ahmed, Obada, and Karam. To Morgane, my source of constant inspiration and motivation and lastly to my friends who helped me through this, Abdulrahman, Anas, Tyler, Jessica, Dana and Oula.

To all surgeons, physicians, researchers and scientists for their care of their patients and for the betterment of humanity.

Contribution to Original Knowledge

The presented work builds on prior knowledge from experts in the field and work done at the division of Plastic Surgery at McGill University in developing tools for competency-based medical education (CBME). The definition and characterization of cognitive competencies in the field of plastic surgery are novel, as well as procedure-specific competencies in breast augmentation. The comparison between reasoning methodology used in surgical care is important in a field with a wide range of ailments (plastic surgery) and is newly presented. The development of cognitive curricula for competency-based education in aesthetic surgery is original, especially for marking and surgical planning. Lastly, the use of cognitive task analysis as a method for oral examination and assessment of cognitive competencies has been introduced through this work. Much of the materials and methods created for this study are novel. All manuscripts presented are published, submitted or to be submitted for publication in peer-reviewed journals specialized in the field of plastic surgery or surgical education.

Contribution of Authors

The division of plastic surgery at McGill university is developing tools for CBME in plastic surgery in line with an international shift in post-graduate clinical training. This study is part of a bigger project developing such tools using breast augmentation as a model for creating tools to assist in CMBE. A prototype for a physical part-task trainer has been made and is currently under further development to tackle the technical skills associated with this procedure. This study focuses on the more important, cognitive skills, required in plastic surgery.

The author has contributed as a first author to all the manuscripts included in this thesis, through planning and executing the research methods, writing of the manuscripts, and production of relevant materials. This project was supervised by Dr. Gilardino, director of the McGill plastic surgery division and an associate professor of surgery at McGill, and Dr. Vassiliou, the associate director of the McGill medical simulation centre and an assistant professor of surgery at McGill. Through their supervision, they provided guidance and refining of the research methodology, offered advice in their distinct fields of expertise, and edited and reviewed the material presented within.

1. Introduction and Rationale

Post-graduate surgical education is evolving into a competency-based model, which calls for a simultaneous change in educational and assessment methods.[1, 2] To that end, many new instructional strategies have been developed and integrated into surgical training, with simulation in the lead.[3-7] However, this integration mostly addressed technical surgical skills that focus on manual dexterity, and speed and efficiency of execution.[4] The challenge is the ability to teach and measure judgment and decision-making.[8-10] The latter two can be encompassed into a skill set named "cognitive competencies" in surgery and are the main focus of this thesis.

Plastic surgery is a specialty that is quite dissimilar in terms of its patients' niche and nature of procedures in comparison to other specialties, a difference pronounced in the role patients play in surgical care that surgeons ought to account for.[11] The matter in hand addresses the education of such cognitive competencies within the realm of this specialty, and attempts to address the planning of such education within competency based education using a breast augmentation model. This introduction addresses the current models in plastic surgery education, the transition in surgical education into CBME and the rationale of this transition. Specific introductions related to the upcoming topics will precede their relative manuscripts to allow for an easy flow of reading.

1.1 Current Models in Aesthetic and Plastic Surgery Training

Current educational models in plastic surgery, are time-based rotations that may or may not provide structured teaching to the residents with the absence of objective evidence of competence at the end of the specified period.[2] Training in a time-based model would be dependent on time and place and doesn't ensure the competence of graduates in the essentials of the specialty.[1] Such models are inadequate and inconsistent in meeting the requirements of developing healthcare systems and patients' needs.[1] Efforts from the royal college of physicians and surgeons of Canada (RCPSC) and the Accreditation council for graduate medical education (ACGME) in the United States have attempted to change this to a model that allows for the demonstration of competence.[2, 12] Lack of assessment tools that are objective in their nature within the surgical field made this shift difficult.[3] Reduction in resident work hours,[13] and calling for increased accountability from interested stakeholders[14] have increased the necessity for such a transition.

Such challenges are more pronounced in the field of training plastic surgery in teaching aesthetic surgeries. Despite being ubiquitously practiced by plastic surgeons worldwide, among several other surgeries, there is great variability in terms of exposure of residents to aesthetic surgeries during their clinical training.[1, 15, 16] In almost all health care systems around the globe, patients pay to private clinics/systems for such procedures, [11, 15] which diminishes the available opportunities for training to residents in aesthetic procedures, which would later compose the mainstay of their private practices.[1, 11] The heterogeneous exposure is accounted for not only by the private nature of the procedures involved but also by the differences in curriculum and experience among training programs within the same educational system and the presence of dedicated rotations or clinics to address such procedures, further limiting their partially independent (supervised) patient care.[1, 15]

In attempts to address such issues, many educators in plastic surgery have developed models, simulation tools and other solutions, only a few of which are competency-based.[1, 3, 5, 17, 18] In North America, large programs with a high flow of cases have established and demonstrated the effectiveness of residents-run clinics to address the exposure issue in aesthetic surgery.[19] Other solutions included several physical simulators, cadaveric models, and computer simulation software.[3, 5, 17, 18] The initial results from such solutions were well perceived, but implementing of many of such solutions will not be feasible in programs that are relatively smaller or lack the budget as they require either funds to produce, maintain, and run, and appropriate infrastructure or a larger patient population. Thus, towards the aim of standardizing education across plastic surgery programs in North America, newer avenues should be explored, while taking such factors into account. An understanding of the tools and innovative ideas in training in plastic surgery reported in the literature to date and qualitative analysis of their nature and quality is an essential step for such an exploration. Part of this project aims to address that through a thorough and systematic review of the literature.

1.2 Competency-Based Medical Education – History and Application in Plastic Surgery

CBME is defined as "…an approach to preparing physicians for practice that is fundamentally oriented to graduate outcome abilities and organized around competencies derived from an analysis of societal and patient needs. It deemphasizes time-based training and promises greater accountability, flexibility, and learner-centeredness".[12] A curriculum that is competency-based focuses more on outcomes that are expected from a competent surgeon, and is designed around attaining them, when compared to a more process-time-based nature of current models.[1] Although many specialties have taken the lead in the development and implementation of such programs, only a few exist, and plastic surgery's implementation of CBME seems to be in its initial steps of planning.[1] Yet, range of simulation and training tools with ranging fidelities exist in plastic surgery.[3, 5, 17, 18] Expert educators in plastic surgery agree on the need for a competency-based training model for aesthetic and plastic surgery, which is becoming the new training paradigm in North America.[1] The RCPSC has emphasized its future directive to implement a CBME framework to the teaching of surgical residency training, arguing that traditional models of post-graduate medical education fail to meet standards of current health care demands.[20, 21] Similarly, the ACGME in the United States in a joint initiative with the American Board of plastic surgery developed the plastic surgery milestone project and have also defined milestones within six identified domains of competency, providing a framework for plastic surgery training in the United States.[22] The advantages of a competency-based curriculum in comparison to the conventional time-based residency program are the accelerated learning based on learner's abilities and the objective and standardized training among the trainees.[1, 2]

The idea of CBME training was initiated more than half a century ago in a proposal from educators to shift training towards objectives and outcomes rather than processes.[23] Throughout the years, however, the focus was put on the process and experience gained over time, leading to outcomes-based education to be based on outcomes rather than process.[1, 2] In 2009, the International CBME Collaborators Group (ICBME Collaborators), part of the Royal College of Physicians and Surgeons of Canada, was formed in an attempt to standardize the concept of CBME.[24] CBME was termed as "an outcomes-based approach to the design, implementation, assessment, and evaluation of medical education programs, using an organizing framework of competencies."[24] To facilitate the transition process, frameworks, such as CanMEDS of the RCPSC[21] and the outcome project of the ACGME,[25] have been outlined to define the terminology and competencies. Competencies are abilities of health care professionals that can be observed, which encompasses knowledge, skills, values, and attitudes.[24] To measure such observable changes and abilities over time, they must be grouped into measurable entities that can demonstrate acquisition of these competencies by the trainees. These "core-competencies" must be defined by field experts, and involved stakeholders and can be used to guide the development and creation of curricula in surgical education.[26]

Measuring multiple core competencies in one setting is not an easy task, and thus, choosing a procedure that covers multiple competencies and teaching and assessing it can provide a measure of competency that applies to similar procedures in the field. Such a procedure can be called an Entrustable Professional Activity (EPA), which permits measuring the acquisition of competencies and monitoring progression through milestones.[21, 24] For instance, correct plane dissection is a skill that can be defined into a sub-competency, as part of a bigger core-competency of effective pocket dissection within an EPA of breast augmentation surgery. Milestones that have to be achieved include various levels of proficiency and complexity of the case being operated on. A resident reaching all milestones as observed by an expert assessor would qualify the trainee to perform such activity unsupervised.[27]

Similar to any transition and change, some educators could be resilient to such change and others that have concerns about implementing and the challenges associated with this process.[1] The main concerns include the lack of clinical relevance of the suggested milestones, inaccuracy in measuring them,[28] lack of tools to measure competencies and outcomes,[29] and other logistical concerns in terms of time and resource allocation.[1, 24, 30] Regardless of the validity of these concerns, the benefits that a CBME model provides supersede these issues, which calls for attempts to overcome them.[1] The advantages of a CBME model is beyond the scope of this work, but to mention a few amongst many, the change to learner-led learning to reach milestones, and availability of evidence to concerned governmental organizations on the competency of graduates.[1, 2, 24] The flexibility this model provides in terms of time required to meet required milestones also allows for earlier graduation that is based on the learner's pace rather, which can vary greatly.[24]

1.3 Objectives

This project aims to develop an understanding and a framework for teaching and assessment of cognitive competencies in aesthetic and plastic surgery by studying a model for breast augmentation surgery. The specific objectives and the rationale are listed below:

Aim 1: To conduct a systematic review of the literature on the ideas, tools and curricula reported thus far in the field of plastic surgery and involved subspecialties.

Rationale: An understanding of the tools and innovative ideas in training in plastic surgery reported in the literature to date and a qualitative analysis of their nature and quality is an essential step for the development of competency-based tools in this field. This will allow a special focus on how cognitive competencies are currently being taught within the realm of plastic surgery.

Aim 2: To conduct a review of the evidence available on the function and effectiveness of Resident-run clinics (RRC) as a model for competency-based training.

Rationale: Resident-run clinics are currently used by many programs to integrate the residents into early practice by providing them with gradual supervised independence. Given their proximity to competency training, appraising their functions will allow a better understanding of their model.

Aim 3: To conduct a cognitive task analysis (CTA) to define cognitive competencies involved in the intra-operative care of patients undergoing breast augmentation.

Rationale: Using breast augmentation as a model surgery for the reasons, cognitive task analysis is a tool that will allows for better understand how experts make decisions and to integrate some of the complexity that is inherent in surgical judgment within this field.

Aim 4: To develop a framework for cognitive competencies within the context of generic mental models in plastic surgery, to assist in creation of teaching and assessment tools for such competencies.

Rationale: Through a comparative qualitative analysis of breast augmentation and flexor tendon repair, and an understanding of the educational literature and the tools reported for plastic surgery education, a model can be developed and adapted to be used by educators as a guide for development of further tools that teach and assess cognitive competencies.

Aim 5: To develop and test a CTA-based curriculum to teach cognitive competencies in Breast Augmentation.

Rationale: Evidence on the ability to teach and test cognitive competencies in plastic surgery is limited. This model helps as a primer to demonstrate the transferability of these competencies using a CTA-based curriculum. Additionally, to aid in the development of assessment models for cognitive competencies in plastic surgery we aim to demonstrate the ability to test these competencies.

Aim 6: To develop and test the effect of a CTA-based curriculum on the ability to mark and plan for a procedure.

Rationale: Marking is an important aspect of pre-operative planning in plastic surgery. The integration of assessment of markings have been highlighted by several experts as a surrogate for surgical planning. Understanding the interplay between marking and cognitive competencies is essential in this field.

2. Towards Competency Training: Interventions in Post-Graduate Plastic Surgery Education

Becher Al-halabi[1,2], Elif Bilgic[2], Melina Vassiliou[2,3], Mirko Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, QC, Canada.
2. Steinberg-Bernstein Centre for Minimally Invasive Surgery, McGill University Health Centre, Montreal, Quebec, Canada
3. Department of Surgery, McGill University Health Centre, Montreal, Quebec, Canada

2.1 Introduction

Post-graduate surgical training is evolving into a competency-based model, creating a need for a simultaneous change in educational and assessment methods used in training.[1, 2] Despite attempts to improve current curricula, the private nature of certain procedures involved in plastic surgery restricts residents' exposure and thus calls for compensatory interventions to adapt for the exposure and monitor competency development.[3-7, 11] Currently employed models are time-based rotations that may or may not provide adequate and structured teaching to residents with little or no objective evidence of competence.[2, 31, 32] In addition to the lack of objective assessment tools,[3] reduction in resident work hours[13] and appeals for increased accountability[14] increase the necessity for improvements in training. This has created a paradigm shift in surgical training led by the RCPSC and ACGME in the United States to demand demonstration of required surgical skillset before graduation.[2, 12]

Due to the broad nature of the specialty of plastic surgery, educators will encounter numerous challenges related to the wide scope of procedures and numerous subspecialty areas (ex. Craniofacial surgery, burn and breast reconstruction, hand surgery, etc.). Even within subspecialty areas that are widely practiced, such as aesthetic surgery, resident exposure during training can be variable.[1, 15, 16] Although some educators in plastic surgery have attempted to address this issue using varying methodologies such as resident-run aesthetic clinics, physical simulators, cadaveric models and computer-based simulation[3, 5, 17, 18] there exists a lack of training methods that concretely demonstrate trainee competence.[19] Also, as will be demonstrated, there is a lack of understanding among developers of the concepts underlying the development of competency-based education and evaluation tools.

An understanding of tools in plastic surgery training reported to date and their objective quality assessment is essential. We aimed to appraise the literature for the availability, quality and competency assessment of educational interventions, propose ways to improve them and guide the further creation of competency-based educational interventions.

2.2 Methods

Search strategy

A systematic review of educational interventions in plastic surgery was conducted according to preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines.[33] The search included electronic databases of the U.S. National Library of Medicine (MEDLINE), Excerpta Medica Database (EMBASE), Cumulative Index to Nursing and Allied Health Literature (CINAHL), PubMed, and Cochrane. Keywords and synonyms combined by Boolean logical operators were: (Plastic Surgery OR Reconstructive Surgery) AND (skill* OR Train* OR competenc* OR educat* OR simulat* OR assess*); syntax was similarly adapted for each database. Search was limited to English from database inception until December 2017 (Figure 2.1). Titles and abstracts of references were used to filter results for relevant studies. Cross-referencing was performed and full texts were obtained for all articles meeting the criteria.

Filter criteria

Inclusion criterion: (1) Specific to plastic surgery, (2) Describes an intervention for teaching / assessing, and (3) Innovative (not previously described). Exclusion criteria: (1) Duplicate articles or data, un-original data (e.g., comments, reviews), (2) Other languages, (3) Hypothetical ideas/models without evaluation, (4) Microsurgical skills ONLY (surplus of evidence), (5) Solely for surgical planning, (6) Undergraduate education, or (7) Non-specific shared procedures.

Data extraction

Data were extracted independently by two reviewers and tabulated with discrepancies discussed until agreement was reached. Data included: authors, year of publication, the field of operation, subjects involved, type and aim of the report, administered intervention, type and magnitude of the outcome, classification of competency involvement, involvement and type of simulation, and targeted learning domain (Bloom's taxonomy: psychomotor, cognitive, and affective domains).[34] Competency involvement was classified as at the level of intervention's: (1) Objectives, (2) Design, or (3) Implementation, based on a systematic definition.[12] Also, educational objectives aligned to competency and roles frameworks by ACGME and RCPSC were identified.[2, 12] The ACGME's competencies are patient care, medical knowledge, practice-based learning, systems-based practice, professionalism and interpersonal skills and communication, while the RCPSC roles within the CanMEDS framework are medical expert, communicator, collaborator, leader, health advocate, scholar and professional.

Quality assessment

The highest level of evidence for the effectiveness of the educational interventions was evaluated using Kirkpatrick's Learning Evaluation Model.[35, 36] This is a four-level reporting model: self-reported opinions (1), evaluating learning (2), evidence of transfer competencies into a change in behavior (3) or patient-related outcomes (4). Validity was assessed utilizing a tool by Beckman et al. for validity evidence of learning/assessment tools on five domains: content, response process, internal structure, relation to other variables, and consequences.[37] Results were recorded from 1-4, with "1" no discussion, to "4" with a detailed description; owing to domains' heterogeneity, a summative score cannot be composed.

Additionally, we used the Medical Education Research Study Quality Instrument (MERSQI), a tool devised to study the effect of funding on the quality of medical education research that was reproduced as a measure of quality.[38-47] The MERSQI is a composite score (Maximum 18), scoring for study design (3), involved institutions and response (3), type of data (3), the validity of the instrument (3), data analysis (3), and outcome (3). However, it doesn't account for all measures of validity, and thus, the two scores mentioned above were added to serve the aims of this review.

2.3 Results

Search results and study characteristics

Of 4307 articles yielded from databases search and following three filtering cycles and cross-referencing (Figure 2.1), a total of 36 interventions were included in the analysis (Table 2.1).

Most reports were descriptive in nature, but those evaluating an intervention were more likely to be competency-based. The physical simulation was implemented in 20 (55.6) of interventions, 10 (50.0) using an inanimate model. With regards to targeted learning domain, psychomotor, cognitive, or affective, 23 (63.9) targeted a mixture of any two domains, and only 6 (16.7) targeted the psychomotor domain. The highest rate of competency assessment was noted in psychomotor and affective domains at 100.0% each. A third of interventions targeting the cognitive domain involved competency assessment. Interventions focused on ACGME competencies of medical knowledge and patient care (Figure 2.2), and CanMEDs role of medical expert (Figure 2.3) is evident with more than 90% involvement.

Outcome assessment, validity, and learning evaluation

Competency assessment was lacking in 7 (19.4) studies, while 16 (44.4) involved competency assessment in the design and only 9 (25.0) at implementation (Table 2.2). Response process validity was highest with a mean of 3.22/4, followed by content validity, 3.03/4. Only three studies (8.30%) reported an evaluation of educational outcomes at the level of results in clinical practice, with an average level of learning of evaluation of 2.36 for all included interventions. The studies included had an average MERSQI score of 10.9 / 18. Only five interventions (13.9%) had a high MERSQI score of fifteen and more. Only two studies (5.60%) were found to be randomized controlled trials, the rest being single group cross-sectional studies, leading to a mean score in the design domain of 1.50 (0.57). On average, the weakest domains within MERSQI were study design and the validity of the evaluation instrument.

Quality assessment

Quality assessment of educational interventions was stratified by involved sub-specialty (Table 2.3). Competency assessment was mostly in reconstructive surgery 12 (37.9), and hand surgery 8 (17.2). Two studies found in ethics and professionalism had the highest average MERSQI score, 13.8/18, and demonstrated the highest level of evaluation of learning, 3.5/4. No other field had an average MERSQI score of more than 13/18. Most reported interventions, 41.7%, were in the field of reconstructive surgery and flap design (Figure 2.4).

2.4 Discussion

Creating educational interventions adapted to competency acquisition among residents should follow methodological planning oriented to the educational environment and societal needs. This includes aligning the tool to the clinical and educational goals that represent essential competencies recognized by experts.[1, 12, 16, 37, 48] The evaluation process should also demonstrate evidence along the competency spectrum at different levels of learning to guide the training process.[35] To that end, this review aimed to appraise available models for competency assessment and areas that lack competency assessment and to provide guidance for creation of interventions that demonstrate competence, thus allowing for better planning of transition towards competency-based training in plastic surgery.[1] The results are best approached in a discussion around instructional design, the practice of creating instruments for knowledge or skill acquisition, integrated with recommendations based on literature on instructional design for competency-based post-graduate training. Such include the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model of instructional design, which will be adapted to facilitate this discussion for its simplicity and procedural organization.[49]

Analysis

A scarcity of interventions assessing skills in plastic surgery was noted with an unequal distribution of targeted domains and competencies with a focus on medical knowledge and patient care competencies, equivalent to the medical expert role. Whereas the focus was less evident towards other competencies domains, such as interpersonal and communication skills, practice-based learning and improvement, professionalism, and system-based practice. Also, almost twenty percent of analyzed interventions lacked involvement of competency assessment at any level; objectives, design, or implementation. Certain fields had clear deficiencies, such as ethics and professionalism, burns, craniofacial and periorbital surgery, paralleling some findings from case-log assessments.[50, 51] Moreover, although evidence for response process and content validity were involved amongst interventions, little objectivity, theory-driven research and applications of other validity measures were noted.[37]

Proper planning is essential in the transformation of teaching strategies.[2, 14, 24] A needs assessment to determine desired learning outcomes, measures of proficiency, and errors to be prevented should include involved stakeholders afflicted by an intervention, namely governing authorities, directors, field experts, tutors, and tutees.[52] Following a needs assessment, identification of areas of weakness in current educational strategies would help prioritize competencies.[1] Following that, assessment of the operational environment and societal needs will help define expected competencies before independent practice.[12, 16] An assessment of available resources, such as space, equipment, finances, personnel, and other means of support, and extent and content of knowledge or skills to be delivered is also essential.[52, 53] This step will aid in ensuring the validity and applicability of designed intervention. Once competencies are identified, milestones can be outlined to provide a process that can be measured and achieved, thus, guiding learners and instructors throughout the learning process.[1] Such milestones focus on general concepts identified by field experts as essential for graduation through a review of clinical evidence and methodological analysis of tasks involved, such as cognitive task analysis (CTA) or hierarchal task analysis (HTA).[1, 8, 52] This will not only provide content validity, but will also establish a balance of targeted learning domains, and involve multiple competencies and roles.

In 2014, the plastic surgery milestones project was introduced jointly between the ACGME and the American board of plastic surgery.[22] Similarly, their counterparts in Canada and the United Kingdom, demonstrating national efforts at standardization of competency training guided by case logs and educational theories.[48, 54-56] Many experts call for the development of such projects through assessment of case logs and in-service examinations to identify areas of deficiencies.[32, 50, 51, 55, 57] The argument for competency-based residency is beyond the scope of this work, with evident international adoption despite arguments against it.[31, 58]

Design and development

Four-fifths of interventions involved some form of competency assessment within the design or implementation process. A multitude of simulation methods was employed in plastic surgery as noted by this review. Most of the simulation was based on physical inanimate models, but the search for simplified, cost-effective models was noted.[59-63] The applicability of any given intervention thus depends on the environment and available support, evident by trends towards the integration of 3D printing and low-cost models.[64-67] Only a few were hybridized models involving immersive clinical (*in situ*) simulation and other simulation media.[68-71] The advent of computer simulation was followed by interactive media on smart media devices in teaching and assessment, as well as the introduction of social media.[72-78]

Demonstration of internal structure validity within design and development, or later in the evaluation process, was also lacking with a mean score of 1.30 / 4 indicating minimal validity evidence on the internal structure without sufficient evidence. Provision of feedback, an important factor in building competence,[79] was evident in a few studies, and ranged from haptics, quantitative biomechanical, to qualitative cognitive feedback, with general evidence of improvement in certain cases.[74, 80-84] This is especially important in enhancing learning experiences and providing objective measures of tracking residents' level at the acquisition of a given skill.[79] Numerous reviews discussed assessment tools used in plastic surgery of various skillsets calling for further research into their correlation to clinical practice and further development.[85, 86]

Generally, skillsets can be divided into technical (psychomotor), and non-technical (cognitive and affective), and training on cognitive skills should precede or be combined with training on psychomotor skills to accelerate their learning.[8, 10, 52, 87] This accelerates technical skills acquisition by decreasing learner's cognitive load and facilitating the cognitive phase of skill learning.[88] The design of interventions follows an appropriate analysis and needs assessment of the skillset required for a specific task, and appropriate planning for development is essential to ensure the accuracy and validity of the material being taught.[1, 2, 52] The process of design also depends on multiple other factors including the educational environment, the skill to be acquired and the experience of the intervention developers.[1, 52] In general, the process is guided by frameworks established through consensus-based on prior experiences, or it can be theory-driven. Once the targeted procedure is identified, it should be deconstructed into identifiable steps using CTA, HTA, field observations, or other methods to identify operative knowledge expected to be known by trainees, common errors, and post-operative complications.[52] The identified material is reviewed and expert consensus (preferably on a national level) on such materials can be established using Delphi methodology or similar methods.[11, 52] The material will be used to develop assessment tools that have to be tested to demonstrate its reliability and validity (construct) and to benchmark expert and novice performance to define a cutoff for competence.[37, 52]

The development of instructional materials follows and is guided by established research in educational psychology for appropriate choice of the instructional design model, and employment of the most effective instruments for the task.[52, 89, 90] For instance, the Canadian Network for Simulation in Healthcare (CNSH) provided four identifiable levels of instructional design (ID) for simulation in healthcare, namely choice of medium, modality, method, and presentation.[90] A "zone of simulation" is also defined by CNSH to guide the employment of simulation, which depends on dynamics of the procedure in terms of acuity (severity) and opportunity (frequency of occurrence), suggesting that simulation would be best employed for procedures with high acuity and low opportunity. Recommendations based on expert consensus suggest the use of synthetic or low fidelity computer models for basic skills training, and investing in cadaveric / tissue models and live animals for training on advanced skills or procedures.[52] A recent systematic review of e-learning demonstrated its effectiveness in the learning of cognitive skills if packaged well with the learning of technical skills within the competence acquisition spectrum.[91] An analysis of simulators in plastic surgery, however, reveals deficiencies in focus on skills and lack of tactile feedback, suggesting the need for further development.[65] The planning of the practice schedule (involving a mix of distributed and deliberate practice), the variability in the level of difficulty, and minimal duration of training required for proficiency is also important to define competence. Lastly, as demonstrated by some interventions, the importance of feedback in learning is invaluable, and thus the development of the intervention should include involvement of formative and summative feedback.[52, 74, 79-84]

Implementation and evaluation

Appraisal of reviewed interventions showed low scores on validity demonstration, evaluation of learning outcomes, and quality of reports. For instance, the majority were cross-sectional or descriptive studies with only two interventions reported following randomized controlled trials.[92, 93] In terms of reporting quality, only five interventions were assessed to have a high MERSQI score [38, 39] (15-18/18).[92-96] The mean average MERSQI score of included studies, 10.9/18 (3.87), was around the average of educational studies reported in the literature of, 9.6/18 (2.60), or average predictive of publishing, 10.7 (2.50).[39]

Before implementing, pre-testing with developed or established assessment tools, validated for that skillset through construct validity, is performed to establish the baseline level of knowledge or skills to demonstrate the effects of the intervention.[52] Using quality assessment tools, such as the ones used in this review, will allow planning of high-quality educational research.[37, 39] For instance, a randomized controlled trial involving two institutions with more than 75% respondents and employing objective assessment methods valid in its internal structure, content, and criterion, with data gathered and analyzed to demonstrate evidence of learning by measuring patient-related clinical outcomes will acquire a perfect (18/18) MERSQI score. Expert consensus exists on using randomized controlled trials to evaluate and validate (using different domains) an educational intervention by comparing an interventional group to standard teaching, evaluate the effect on post-test scores and the learning curve in the operating room, and further develop the intervention by gathering feedback and studying learners' skill retention.[52]

Limitations and future directives

Exclusion of microsurgery for the surplus of data and the availability of well-established reviews on the topic could have also affected the results. With the shift in trends of plastic surgery education to demonstrate competency and increasing accountability, we hope this review can provide a primer, in the ongoing development of competency-based educational tools in plastic surgery, of superior quality. Evidence from our review suggests a lack of competency assessment integration in the current educational interventions, especially those targeting the cognitive domain of learning.

2.5 Conclusions

A systematic review of the educational literature in plastic surgery was conducted to assess the status and quality of reported educational interventions in plastic surgery and to help guide the creation of further tools that assure competency acquirement among trainees. Overall, the reviewed literature was of average quality, with limited involvement of competency assessment. This calls for improvement in conducted educational research in this field, and the need for an increased focus on teaching and assessing of the cognitive domain.

3. Examples of Current Tools Used in Plastic Surgery Education

3.1 Aesthetic Surgery:

In 1973, Conway introduced videotaped operations to teach rhinoplasties within a 5-day course, allowing better visualization and information assimilation, with users reporting a positive attitude towards it as a medium of delivery.[97] Wright similarly advocated in 1981 using external rhino-septoplasty, to the intra-nasal approach, to provide in-situ visualization, accelerate learning, and demonstrate normal and deformed nasal anatomy without affecting aesthetic outcomes.[68] With the advent of technology, computerized imaging and artificial-intelligence-based simulation systems were introduced to allow safe experimentation and development of judgement in rhinoplasty and facial plastic surgery.[80, 98] Datasheets were described by Tardy et al. as a method of self-learning through graphic record-keeping of rhinoplasties, allowing for long-term follow-up and teaching.[99]

In 2005, Jacovella studied the effect of a 40 hours cadaver-based rhinoplasty training on skill development by objectively assessing cosmetic results in trainees against controls, and found a significant difference in their performance (76% vs. 4% scoring "Very Good").[92] Away from cadaveric models, Zabaneh et al. described in 2009 using computed tomography (CT) data to develop an anatomically accurate "hands-on" rhinoplasty training module of silicone to teach and assess competency.[100] Similar, anatomically representative, models were also described using animal cadaveric models, such as chicken sternal cartilages and sheep heads for the learning of rhinoplasties as well, with positive results in terms of learners' attitudes.[101, 102] Recently, in an attempt to assess technical skills, Glarner and others used video-based motion analysis of six reduction mammoplasties to quantify spatiotemporal properties of the operators' hands. Their findings suggest a describable and measured differences in pattern and style of hand motion between expert and learning surgeons in terms of movement conservation.[77] Using a glass mounted camera, Valente et al. reported the effectiveness of tele broadcasting a malar fat pad removal procedure to demonstrate using telemedicine to be an easily accessed good learning experience that allowed participants to become familiar with performing the procedure.[103]

Art in aesthetic surgery

Thompson and others introduced in 1972 a simple art course for plastic surgeons involving 16 hours of art class time (including drawing, clay modelling, molding and casting) that they found to improve trainees judgement of proportions, records of deformity and techniques, and familiarity with molding and casting for surgical planning.[104] To demonstrate the effect of art education on aesthetic surgery, Guneron et al. allowed 13 junior plastic surgeons to a pretest of a facial charcoal drawing, which was followed by a six hours course of history and appreciation of artistic concepts, along with three hands-on sessions in sculpting; not surprisingly, they found an improvement in the charting of anatomical details and an improvement in attitudes of participants towards the importance of art in this field.[105] Similar interventions to improve sculpturing techniques among plastic surgeons to augment visual perception, sense of touch, and 3D data storage, especially in facial aesthetics, were also replicated.[106, 107]

3.2 Burn Surgery

Interventions that addressed burn surgery were limited. As part of a general concept of the use of excised human tissue for education, Iqbal et al. in 2005 advocated for consenting abdominoplasty patients to allow the use of their discarded abdominal skin and fat as training material for skin grafting[108], along with other authors.[109] Within the same realm, in 2007, Tadiparthi suggested that a simple tweak of marking the cutting border on a three-inch dermatome blade will allow inexperienced trainees to take better graft, and avoid disfiguring results of inadequate grafting.[110] Medical students have taken a part in postgraduate trainees' burn education by volunteering as live manikins with the make-up of burn clinical signs within an in situ-simulated acute burn management.[111] Lastly, the "burns suite" is an immersive simulation environment for burns education that utilizes a pediatric burn resuscitation scenario designed on principles of burn management refined using cognitive task analysis (CTA), with high reliability, high realism, and at a low cost.[5]

3.3 Craniofacial Surgery

The first simulation model for training on craniosynostosis surgery is a cadaveric sheep head, reported in 2006, that allows sub-periosteal and periorbital dissection, bi-frontal bone flap elevation, supraorbital bar, and fronto-orbital remodelling and was found to simulate pediatric and adult craniofacial surgery.[112] A web-based simulation system developed using CT images and reported by Schendel et al. in 2009, allowed for a highly realistic real-time manipulation and simulation of outcome for craniofacial surgery planning and education.[113] To monitor intra-operative results in the management of facial fractures, Ibrahim and others advocated in 2011 for the use of intra-operative CT scans as a tool to provide trainees with real-time feedback on their reduction and improve documentation of outcome.[114] An anatomically accurate physical inanimate simulation model of pediatric craniosynostosis was developed later in 2014 to allow for simulation of bi-parietal remodelling used in scaphocephaly, with all the steps involved, including emergency bleeding from a simulated superior sagittal sinus, adding to the realism provided by the model.[115] In terms of competency assessment, however, only one tool was reported by Flores et al. in 2014 to assess the arch bar placement (ABPAS) and dental wire handling, which is composed of a 48-point scale (23 task-specific and 25 global) that was validated through discriminating between experienced and non-experienced operators.[95]

Oculoplastic surgery

Reports on oculoplastic surgery are quite limited. Pfaff and others reported using of pig eyelids for eyelid repair due to similarity with human eyelids, apart from the tarsus resistance to suturing needles, allowing simulation of closure techniques and eyelid laceration repair.[116] Sheep heads have been also suggested to simulate eyelid surgery as a cadaveric physical model.[117] Also, an assessment tool was described and validated in terms of face and content validity with > 90% agreement to aid in oculoplastic surgical evaluation in nine tasks specific to tarsal strip procedure and nine global rating scales.[118]

3.4 Pediatric Plastic Surgery

Many attempts have been made to simulate cleft surgery of the palate, the first reported by Cohen et al. in 1996 using a physical simulator of human cleft molded into a skull to allow raising mucoperiosteal flaps to assist in training.[119] Mathwes et al. reported a similar teaching device of latex or Styrofoam sheet for Furlow palatoplasty for resident education[120]; others used sticky notes for z-plasty flap mechanics.[121] Web-based materials and case review systems to allow reviewing more than 750 malformations,[122] a series of computer graphics of three-dimensional animation (as compact disks) and live surgical footage through video-conferencing, were also used.[73] Many models were further developed for simulation of cleft lip repair, such as on to track the surgeon's motion and provide real-time haptic feedback during the procedure validated by surgeons performing better than non-experts.[74] Another recent model developed through computer-aided design using coloured prosthetic silicone to simulate and teach Cheiloplasty.[123] Other inanimate physical models to simulate cleft palate repair included latex (rubber dam and surgical gloves)[124], painted latex and foam within a closed space (oral cavity)[125], and alginate impression with latex to allow intra-oral cleft surgery practice.[126] Uygur et al. also described using sheep heads for cleft palate training as well.[117] Lastly, the use of standardized patients through a validated OSCE of parents of a 1-month old baby with unilateral cleft palate demonstrated differentiation between junior and senior residents in terms of knowledge, marking, and examined all ACGME core competencies.[127]

3.5 Hand Surgery

Several models were described for training on flexor tendon repair, some were wooden set-ups with synthetic pulley systems [128], dental rolls as tendon cut ends [129], bungee cords [130], and acrylic bones with silicon-rubber tendons, and tape for pulleys.[131] Using an objective global rating scale, Ingraham et al. displayed in 2009 the effectiveness of physical models, using a 1 cm in diameter synthetic bait worm model, in improving quality and performance of zone IV tendon repair, and that exposure to this training led to better results on a cadaveric model; they also reported other educational approaches that increased residents' confidence and improved repair.[132, 133] Other physical animal cadaveric models were also described to use tendons of pig's trotter on a plastic setup[134], porcine forelimb digital flexor tendons to train on zone II flexor tendon repair [135], and porcine trotters.[59] CTA was also used to design a 10 minutes multimedia module to teach decision-making in flexor tendon repair that led to significantly better results, based on an objective checklist and a talk-aloud test, when compared to traditional learning.[18] A similar curriculum was designed to study the effect a focused tutorial has on zone II flexor tendon repairs noting a significant improvement in biomechanical properties (load required to generate a 2-mm gap and ultimate breakage), and tendon purchase and confidence post tutorial, and maintenance of gains six months later.[136] Resistance for gap formation, breaking strength and gliding resistance were used to provide feedback of flexor tendon repair in another study, which demonstrated better repair (strength and smoothness) when such feedback is given, compared to none.[82] An objective assessment tool was similarly introduced to test different stages of repair using ultimate tensile strength, 3mm gap force, yield force, and stiffness.[60] Surgical gloves have been reported for use to demonstrate and plan hand flaps as a model that simulates skin plasticity by Skoff et al. in 1994.[137] Another example used a plastic flectional hand model covered in layers of coloured latex to simulate hand flaps.[138] Moreover, cadaveric chicken femurs were also used in a hand trauma model for simulating fracture fixation, bone anchoring, tendon repair, wound debridement and suturing.[61]

3.6 Reconstructive Surgery

Multiple interventions have been described in the field of reconstruction, with the majority being concentrated on flaps design. Physical models have been reported for skin surgery and manipulation, and subcutaneous tissue, for instance using sponge mounted porcine skin.[139] An objective evaluation of suturing skills to provide haptic feedback based on the force used on a stylus, stitch straightness, and time consumed allowed for improvement in time and stitch accuracy.[81] Other interventions include a computer simulator to teach interpretations of Doppler signal in assessing free tissue transfer,[140] and a simple device to aid learning peri-areolar marking of Lejour's mammoplasty using a clean outer PVC casing bent to shape.[141]

Flaps design

Physical models demonstrating flaps mechanics include a wide range of inanimate materials, such as a 4*8" gauze pad,[142] 2 cm thick foam rubber,[143] latex-free elastic bandage,[144] and biosynthetic dressing.[145] Other model developers used a styrene mannequin head, covered with cling film [75], or covered a shaped thermoplastic frame with polychloroprene fabric.[146] Anatomically accurate models include plaster covered with an adhesive dressing to plan facial flaps[147], a polystyrene head covered in layers of pigmented latex and sloops to simulate nerves and vessels[138], and a silicone-based facial model with underlying fabric mesh to simulate Mohs surgery and consequent coverage.[148] In comparison to traditional teaching on pigs' feet, a model made of polyurethane foam was preferred by learners.[149] Moreover, improvement of scores was noted using cotton covered with polyethylene stretch film on subjective assessment,[150] foam rubber covering on subjective and objective assessment,[151] and subjective improvement in flap planning and design following training on soft silicone rubber on top of wax[152] and a model made with coloured yarn.[153] Training on a model made of polyurethane with a removable flap island and connecting vessels used to simulate raising a forearm flap led to significantly better results in terms of knowledge as well.[96] Similar to the aforementioned marking aid, template tools in forms of rules were designed to rhombic and Limberg flaps, amongst others.[154, 155]

Biological models were also accustomed to teaching and assessing flaps design. Such models included mannequin heads draped with porcine skin[156], using cattle digits with high learner acceptance[157], and using a live pig model for internal mammary free flap transfer and microsurgical anastomosis with high fidelity to a human model.[158] Furthermore, a five minutes individualized training and feedback provided to learners on a pig thigh model led to significant improvement on scores on a checklist and global rating scale. In an attempt to salvage excised tissue for use in teaching, dermo-lipectomies skin excess was used to teach suturing, local flaps, grafts harvesting, and flap dissection,[109] and even microvascular anastomosis with significant improvement in subjective assessment of trainee's skills and operative time following practice on such models.[159] On using cadavers, regional perfusion of human cadaveric models through cannulation of targeted vessels increase realism and fidelity in raising multiple fascio-cutaneous and osteo-cutaneous flap and improving the learning experience of free flaps transfer.[160, 161] Even in-situ, surgeons have modified certain techniques in live operations, such as the submental flap to ease resident learning with no change in complications,[162] and the post-auricular area as a safe environment for surgeons in training to learn flap reconstruction due to its concealment and the forgiving properties of the skin in that regions.[163]

Technology has been also implemented in flaps education. Clinical images displayed on computer slides that are manipulated and marked-up with presentation software provide an interactive environment to teach and assess flap design.[63, 72] More advanced computer-based models have been developed using soft-ware based virtual surgery simulation to allow for three-dimensional visualization of multiple flaps, among others.[70, 164] A pilot of such a system for fronto-orbital advancement showed a multiple-choice-questions (MCQs) based cognitive improvement among users.[70] A similar effect was also demonstrated by a latissimus dorsi musculocutaneous flap surgical simulator with statistically significant improvement in MCQ scores.[164] More realistic touch-based interactive system was also developed to train Z-plasties in an engaging environment using real-time deformational response.[165]

Ear reconstruction

Anatomically representative silicone-based molds of rib cartilages have been created to allow practicing and teaching carving in preparation of the framework for ear reconstruction,[166] with reported blinded evidence of improved carving quality when an instructional session is followed by practice using such models.[93] More realistic models include the use of porcine rib cartilages to train on the carving of an ear framework[167], and sheep heads for external ear reconstruction.[117]

3.7 Ethics and Professionalism

The teaching of this domain has been limited to two studies. The first of six subjects by Davis et al. that was published in 2011 involved a thirty minutes clinical encounter with standardized patients within an objective standardized clinical examination (OSCE) on Melanoma that was followed by a written test.[84] Although the OSCE assessed all six competency domains, OSCEs were reported to be effective at assessing professionalism and interpersonal communication skills, among the other domains, and feedback from which helped participants in directing their learning. Hultman et al. studied the effect of a course on different topics of professionalism and different levels of learning evaluation: attitudes, knowledge, behaviours and clinical outcome at six months intervals.[168] An improvement on all levels, including a decline of infractions and patient complaints and an improvement in patient satisfaction, was noted six months following the course.

4. The Role of Resident Run Clinics for Aesthetic Surgery Training in the Context of Competency-Based Plastic Surgery Education

Becher Al-halabi[1], Jessica Hazan[1], Tyler Safran[1], Mirko S. Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, Canada.

4.1 Introduction

Surgical education in North America is shifting towards CBME, whereby trainee performance is measured and demonstrated through objective milestones.[1] In response to this curriculum reform, the ACGME has defined core competencies that all plastic surgery residents are expected to attain upon program completion, with aesthetic surgical education being among these competencies.[169-171] As highlighted by Murray and Baker, aesthetic surgery education distinguishes plastic surgery from other competing specialties, yet hands-on training in aesthetic plastic surgery is challenging mainly due to patient reluctance to have trainees participate in their procedures.[1, 169, 170] Suggestions for improvement by experts include standardizing curricula across programs, shortening general surgery training, increasing hands-on training and faculty involvement, community rotations, fellowships in aesthetic surgery and implementing resident-run clinics (RRC).[172-176] With an increase in RRCs and continuous transition in plastic surgery education into a milestones-based model, this study explores RRCs as a model for competency-based aesthetic surgery training in terms of best practices and outcomes.[177, 178]

4.2 Current Methods of Aesthetic Surgery Training

Current methods of aesthetic surgery training differ across residency programs. Most programs employ designated cosmetic surgery rotations and integrate didactic teaching, while few have an RRC dedicated to aesthetic surgery training.[174, 179, 180] Designated rotations are usually single or multiple 1-6-month-periods whereby residents assist in surgery with variable exposure to the consultation and follow-up process.[181, 182] At some academic centers, the variability and extent of cosmetic procedures performed are minimal.[183] Notably, private practice patients frequently undergo wide-awake procedures under local anesthesia, which may further limit the degree of intra-operative teaching.[176]

4.3 Typical Resident Run Clinic in Aesthetic Plastic Surgery

During the first clinical visit, the senior resident performs a complete evaluation of the patient, with or without an attending present, and formulates a preliminary care plan.[184-194] During this time, the resident can counsel the patient on a given aesthetic surgery procedure and discuss the risks and benefits of surgery or other interventions. Initial consultations usually cost a ranging non-refundable fee of $25-150 that can later be applied toward surgical expenses.[185, 193, 195, 196] Certain clinics do not charge consultation fees if the attending is not present during the clinical encounter.[184, 192, 196] RRCs may choose to perform pre-consultation screening to identify eligible patients in advance.[171] Free screening visits at the beginning of each rotation can promote the practice, with cost deficits offset by future revenue.[185, 186]

The most common reasons for not accepting consultations are unavailable services, issues with insurance, patient's BMI, or comorbidity.[184] The majority of consultations involve ageing face and eyelids in older patients, as well as nasal, breast and body contouring in younger patients.[185, 190, 196-198] A second re-evaluation visit entails a review of the plan with the attending, surgical booking, and routine pre-operative photography.[185, 190, 194, 196] Clear disclosure on all costs associated with consultations, follow-ups, surgeries, and management of complications is given.[186, 190, 199] To improve compliance to treatment and follow-up all payments are submitted in advance.[185, 189, 196]

Operative time can be provided or donated by the attending, and the residents should be responsible for booking their surgeries.[185, 186, 188-190, 195, 196] Most cases are done under general anesthesia.[194] Patients are charged, in part or full, for the anesthetic, hospital, surgical and overnight admission fees.[185, 186, 188, 189, 196, 200] Despite the expected increase in total-surgical-time given resident involvement, an autonomously working resident can be safe when adequately supervised.[201-204] Adequate supervision entails that an attending is present or easily available, particularly for more complex or involved procedures. Intra-operatively, the attending's presence follows a progressive autonomy model.[185-187, 190, 192, 195] That is, the degree of attending involvement depends on the comfort and experience of the resident.

The resident is held accountable as the primary surgeon on all documentation and patient information material.[188, 189, 191, 196, 199] A pre-formulated post-operative plan is followed and patients are encouraged to adhere to a follow-up timeline, consisting of 3-4 visits on average.[185, 188, 192] The follow-up includes post-operative photographs and satisfaction surveys.[194] Residents remain on call for their cases, and in charge of follow-up and the management of any complications.[186, 190, 195] A policy for fees associated with revisional surgery should be discussed and agreed upon before the first intervention.[190, 191, 196, 205] When complications arise, an open disclosure session can be held with the involved resident and attending to address dissatisfaction and provide feedback.[196]

4.4 Management of Complications

As with any clinic, RRCs are at risk for complications.[186, 190, 201-204] Ethical issues arise following unfavourable results, especially in the absence of direct supervision in certain institutions.[15, 184] This mandates designation of responsibility, proper ethical education and medical liability insurance to help navigate conflicts between educational goals and patients' safety and expectations.[15, 184, 189, 206] Residents require liability insurance and sometimes patients require cosmetic medical insurance.[194, 196] Clear patient understanding of residents as surgeons-in-training under supervision is essential.[195] Only 35% of patients clearly understand residents' designated roles, and most expect to be asked for permission before the resident assumes responsibility.[186, 198, 207] Patient education tools improve informed consent and understanding of residents' roles and thus shared-decision-making and satisfaction by approximating expectation.[194, 195, 208, 209] Nevertheless, evidence suggests that satisfaction rates in RRCs are comparable to that of private centers.[185, 186, 188, 196, 199, 210] Low satisfaction is likely related to the technical learning curve, unrealistic patient expectations, resident demeanor, communication and time spent in an interview, but can also relate to the degree of supervision and staff involvement.[199] Other common reasons for dissatisfaction following surgery included scarring, asymmetry, complications and unmatched expectations.[191, 199]

Finally, cosmetic patients require personalized service and privacy, which is contrary to academic practices whereby multiple trainees partake in patient care.[184, 211] This patient population demands care by selected experts, restricting residents' exposure to private-clinic-based rotations.[172, 184, 211] Reluctance stems from the perceived negative effects on their aesthetic outcomes, which patients pay for out-of-pocket. As such, most of the learning is obtained by observing or assisting surgical attendings perform aesthetic surgery. Besides, with many procedures performed in an awake patient under local anesthesia or light sedation, teaching may be further limited during these types of interventions.[185] Financial incentives are thought to be a crucial factor in recruiting patients for surgery carried out by trainees.[184] RRCs cater to a niche of patients that are attracted to lowered prices in exchange for resident involvement while being supervised.[187, 195]

4.5 Degree of Exposure and Non-Surgical Techniques

The most commonly performed procedures are body contouring and breast surgeries, and across all programs, residents report the highest confidence in performing these surgeries.[172-174, 212-214] The exceptions are mastopexy, advanced and lower body contouring and endoscopic breast augmentation.[173, 174, 213] Most graduates lack comfort in facial surgical procedures, such as facelifts and rhinoplasties.[172-174, 212-214] In contrast, graduates feel comfortable performing platysma and brow lifts, yet their program directors feel they lacked comfort in an open or endoscopic brow lift, and chin or facial implants.[174, 213, 214] Finally, residents lack exposure in non-invasive procedures including endoscopic techniques, peels, skincare, injectables, laser resurfacing and hair transplantation.[172-174, 213, 214]

4.6 Overcoming Barriers

RRCs are difficult to initiate due to a lack of public knowledge and may not generate enough revenue to survive.[193, 195] Media advertisements can be used to promote free screening visits or the launch of new clinics or rotations.[184-186, 190, 198] Alternatively, patient satisfaction driving "word of mouth" can also increase referrals.[189, 193, 195, 196, 199] Most RRCs operate on a not-for-profit basis. Revenue from the clinic is usually returned to the program or used for compensation of clinic staff.[186, 194-196] For example, some clinics hire administrative assistants, freeing residents from these time-consuming tasks.[186, 194, 195] Revenue can also be used to provide residents with housing, travel, books, and stipends.[181, 189, 196] Some programs provide attending staff with educational reimbursements, such as a percentage of insurance claims.[184, 205]

Despite having garnered support by plastic surgery educators,[183, 190] the lack of RRC standardization is multifactorial. Most of the available research shows financial viability despite high risk for litigation and extensive resources and personnel but is highly variable depending on location and staff compensation.[179, 194] In terms of facilities, an offsite set-up requires fixed costs, expensive equipment (lasers, endoscopes, etc.) and can be logistically difficult for residents to reach. Although offsite clinics avoid the need for sharing resources and space, they must be fully accredited.[190, 198] For revenue optimization, an understanding of economic elasticity is essential to appropriately price services and optimize deficiency coverage while maintaining viability.[187] The American council of academic plastic surgeons (ACAPS) also recognizes costs, staff oversight, malpractice concerns, and administrative issues as barriers to setting up RRCs.[196, 205] Administration, logistics and billing are essential for a practice's success and evidence shows that residents lack knowledge on appropriate documentation and coding.[184, 215] This requires education on strategic marketing, accounting and finance, economic forces of competition, supply chain, and regulations, in the context of office-based surgery and aesthetic services, which is lacking.[179, 216, 217] In addition, due to the rotating nature of residents' involvement, residents lack exposure to all aspects of running a practice and may not complete their patients' follow-up as they graduate or move onto other rotations.[199] Other administrative issues lie in legal accountability of complications or unfavourable results.[15, 184]

Establishing RRCs can be challenging due to a lack of faculty or program director/residency program committee approval, or a public perception of residents being inexperienced or unqualified for their aesthetic surgery needs.[184, 193] Operating room availability and adequate clinic time may also be roadblocks.[184, 196, 205] Moreover, inadequate funding and negative attitudes from residents towards RRCs are also reported.[194, 212] Infrequently, local private aesthetic clinics can perceive the introduction of an RRC as competition.[185, 191, 195] To avoid damaging relationships with local private cosmetic surgeons, RRCs should be advertised as a learning resource targeted to patients with inadequate funding, and those with complex medical problems to allow residents to practice patient screening.[218] This is possible as some clinics set up within a hospital enviornment, allowing access to more intensive monitoring and safer practices.

4.7 Rationale for Resident Run Clinics in CBME in Aesthetic Surgery

The ACGME has introduced a CBME model in hopes of providing trainees with the tools to meet societal expectations upon transition into independent practice. RRCs are semi-independent environments that employ all aspects of this competency framework and provide a milestone-based education through progressive autonomy.[179] Since the quality of care in aesthetics is centralized around patient satisfaction, continuity of care is essential for improving resident performance.[199, 210] As such, it provides a society-catered educational opportunity that well prepares residents for post-graduation practice while maintaining an equivalent safety profile.

Using the competencies of the ACGME and the roles of the RCPSC as a framework (Figure 4.1), comparing the currently employed models in aesthetics training to RRCs will highlight the importance of the latter in the transition towards CBME (see table 4.1).[2, 12] While didactic teachings and designated rotations can provide medical knowledge and some exposure to patient care (medical expert role), RRCs employ a unique, semi-autonomous and immersive learning environment to improve knowledge and skill acquisition through applicative learning.[185-187, 190, 192, 195] Moreover, RRCs provide residents with prime opportunities to develop their professionalism and their roles as health advocates by allowing them direct patient exposure during a primary visit in a milieu that varies from that in academic practice.[184-194] This is further augmented by the accountability bestowed on the resident in terms of outcomes, which is lacking in traditional teaching models of aesthetic surgery.[188, 189, 191, 196, 199] This learning environment is also compatible with the plastic surgery milestone project by providing measurable and attainable levels of experience and accountability and help identify learning gaps.[178] As such, the role of RRCs within CBME becomes especially important with the implementation of the Next Accreditation System, with evidence of validity and effectiveness emerging from the application on other surgical programs.[54, 219-221] With variability in response and preparedness among plastic surgery programs, the effects within the accreditation process can range from suggesting programs where residents have difficulties in attaining milestones to establish RRCs or making them essential for accreditation given the weight given to aesthetic surgery within the established plastic surgery milestones.[54, 178]

When residents are allowed to take charge of patient care, RRCs develop skills related to the non-technical aspects of care (cognitive competencies) as well, which are often deficient in other models of aesthetic training.[200, 205, 222-224] These non-technical skills include communication, leadership, task management, and practice management. Besides, such learning environments involve a trial and error process that most trainees will only go on to experience in their first year of practice, as well as autonomous learning that allows residents to graduate with more confidence.[184, 192, 214] RRCs are, therefore, unique in providing an opportunity to partake in all aspects of patient care, including pre-operative planning and long-term follow-up of aesthetic surgical cases compared to other models.[182, 185] Exposure to these skills is imperative for practice and system-based learning, where residents assume the roles of collaborators with other team members, leaders of their practice and communicators through direct patient care, patient education and plan formation.[186, 190, 195] Lastly, several RRCs involve their residents in learning through evidence-based-medicine and studying the clinic's outcomes, thus developing their analytical and research skills.[17, 188, 194, 199, 210]

In such a transition to CBME, the ability to measure the progress and competency in the aforementioned skills and roles becomes a priority; RRCs provide an optimal environment for such assessments as well. Attainment of the six ACGME core competencies can be measured using 360-degree evaluations.[17, 225, 226] That is, feedback is obtained from all parties involved, including subjective self-evaluations. Establishing learning objectives, providing feedback in real-time, completing case logs and attending mortality-morbidity meetings are also methods commonly employed for performance improvement.[186, 189, 192, 205, 223] A recent survey of the effect of the increased ACGME case log minimum requirements demonstrated an increase in RRCs, designated rotations, and self-perceived resident preparedness; this transition was generally thought to be beneficial for training.[177] An autonomy score describing the attending's role, ranging from "available" to "scrubbed for the entire case," has been used to track autonomy progression. This form of graded autonomy provides stable soil for competency development.[172, 179, 181, 184, 188, 191] Application of formal tools such as client satisfaction questionnaire-8 (CSQ8) and FACE-Q among others can also be used to track resident performance and provide feedback for improvement.[191, 222, 227]

4.8 Conclusions

Current research on RRCs in aesthetic surgery mainly consists of statistical compilations from surveys targeting residents and program directors.[15, 170, 171, 174, 180, 185, 213, 228] There remains a gap between the perception of faculty and residents concerning aesthetic training. Eighty-eight percent of program directors were "satisfied" or "very satisfied" with cosmetic training, compared to only 32% of residents.[199] Accordingly, a 2016 ASAPS survey demonstrated that both parties agreed that RRCs were the best modality for aesthetic surgery teaching.[172-174, 179, 212-214] Members of ACAPS were also in support of RRCs and did not perceive them as being a liability.[179] The present authors provide further support for the merit of RRCs, highlighting how the autonomous learning platform can serve as a vehicle for competency-based learning within aesthetic surgery training. As such, RRCs may provide teaching programs and faculty with a tool to facilitate the challenging shift towards competency-based medical education, which has already become the evolving standard for North American surgical education.

5. Breast Augmentation to Model Educational Interventions Design in Plastic Surgery

Breast augmentation is the most commonly practiced aesthetic surgery in the United States of America but constitutes little of the training plastic surgery trainees receive.[229] This procedure has been specifically identified by experts as an index aesthetic procedure (EPA) that covers many of the competencies needed to perform other aesthetic procedures, and can thus be used as a model for the design of educational interventions for similar procedures.[11] The literature on procedure exposure reports less exposure and confidence among plastic surgery residents in aesthetic surgeries, particularly breast augmentation.[185, 189, 230] Besides, data extracted from a national database of resident operative log demonstrated decreased participation in these procedures.[11] Similar concerns have been reported in the literature.[15, 197, 231, 232] Surveys of the American plastic surgery training programs demonstrated low confidence of residents in aesthetic cases despite the introducing interventions to address such issues, for instance, residents-run aesthetic clinics and dedicated aesthetics rotations.[174] Similar reports are also found in Canadian programs with lower confidence in Breast augmentation, among other aesthetic procedures.[230] In addition to the demonstrated need for teaching technical skills of this procedure, the outcomes of the procedure itself are mostly dependent on the decisions made throughout the planning and execution of patient care.[233-235] This is evident clinically by high indictment rates of breast augmentation cases, with iatrogenic injuries being the most important factor leading to the award of damage or settlements to the plaintiffs.[236-238] A study of the litigations of cosmetic plastic surgery concluded that the majority are a result of improper pre-operative planning and patient selection and/or deficiency in communication with the patient rather than technical errors.[239] Thus, addressing the cognitive aspect of this procedure is also as important in building competent surgeons.[10, 240]

6. Defining Cognitive Competencies for Breast Augmentation – A primer

Becher Al-halabi[1,2], Amin Madani[2,3], Melina Vassiliou[2,3], Mirko Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, QC, Canada.
2. Steinberg-Bernstein Centre for Minimally Invasive Surgery, McGill University Health Centre, Montreal, Quebec, Canada
3. Department of Surgery, McGill University Health Centre, Montreal, Quebec, Canada

6.1 Introduction

Breast augmentation is the most commonly practiced aesthetic surgical procedure in the United States of America based on the 2018 statistical data of the American society of plastic surgeons (ASPS).[229] Despite this, it constitutes a disproportionately small proportion of plastic surgery residents' training, resulting in limited experience and confidence among graduates.[185, 189, 230] Similarly, data extracted from national databases of operative logs suggests very low exposure to aesthetic surgeries amongst trainees[11] – a finding that is shared amongst experts.[15, 197, 231, 232] While multiple interventions, such as resident-run aesthetic clinics and dedicated aesthetics rotations attempted to rectify this, pitfalls relating to aesthetic-surgery training remain a significant concern.[174, 230]

Evidence suggests that technical competence alone is insufficient to ensure optimal outcomes, as many important decisions are made throughout the perioperative stage of patient care, which can have a significant impact on clinical and patient-reported outcomes.[233-235] Despite being a routine procedure, the re-operation rates after primary augmentations are high, especially related to volume dis-satisfaction related to decision-making.[241] A study of litigations involving cosmetic surgeries suggests that the majority of cases are a result of improper pre-operative planning or deficiencies in communication, as opposed to purely technical errors.[239] Therefore, clinical and intra-operative judgment seem to be skill sets that are central to the development of surgical expertise.[10, 240] Advanced cognitive skills, which allow surgeons to exercise sound judgment and make effective decisions require a robust mental model that is developed through the acquisition of knowledge and experience.[242] Nevertheless, these are complex skills that remain highly ill-defined and subjective. More importantly, experts agree that current pedagogical models for developing these aptitudes amongst surgical trainees are insufficient, non-systematic, and highly error-prone.[9, 10, 88, 239, 240, 243, 244]

It is therefore conceivable that improving surgical training by focusing on elements such as forward-planning, error prevention and detection, and the association of decision-making and its integration with technical training, can have a significant effect on surgical performance and contribute to enhancing patient outcomes.[87, 245, 246] Various qualitative methodologies from behavioural sciences such as cognitive task analyses (CTA) of experts have been adapted to surgical education in an attempt to define the mental processes required to perform various tasks in and out of the operating room. Such objective conceptual frameworks can provide the means to develop novel curricula and assessment tools to objectively measure performance.[8, 9, 247] This qualitative study aims to characterize and define the various cognitive competencies and pitfalls in breast augmentation surgery.

6.2 Methods

In this study, qualitative methods were used to explore expert mental processes followed by inductive data analysis to compile the resulting data (Figure 6.1). This study focused mainly on primary breast augmentation, without adjunct surgeries, using an inframammary approach due to its frequency and involvement of surgical concepts shared with other procedures. The study protocol was approved by the institutional review board and conforms to the Canadian Tri-Council Policy Statement of Ethical Conduct.

Task analysis design

A systematic and theory-driven approach was employed to identify cognitive competencies involved in breast augmentation by performing a CTA.[8, 248-250] A CTA is a qualitative methodology often used to analyze the various steps and decisions involved in a procedure by deconstructing and analyzing complex tasks that involve higher-order cognition.[8, 244, 247, 248, 250] In preparation for the interviews, 25 steps in breast augmentation, previously described,[11] were used to develop CTA interviews guided by content from textbooks,[251-253] litigation case studies,[236-239] original research, operative field observations and video materials on the plastic surgery educational network (PSEN) to add depth to the CTA and help extract expertise from SMEs.[241, 254-263] A semi-structured, case-based, CTA interview was designed with 20 different cognitive probes to elicit experts' proficient cognitive processing (Table 6.1).

Subject matter experts' interviews

Semi-structured interviews were conducted with subject matter experts (SMEs). SMEs were defined as those who had performed at least 50 breast augmentation surgeries and had at least three years of experience, time to achieve at least 50 breast augmentations. To increase the breadth of data and to develop a more comprehensive CTA, a variety of SMEs were approached for participation with a wide range of demographics and training. Informed and consenting respondents de-briefed on the interview process and presented with 20 cognitive probes to elicit discussions. The SMEs were encouraged to ask for cues and freely discuss their decisions, and cues leading to decisions. Interviews continued until data saturation, defined by the absence of unique responses for two consecutive interviews. Interviewers minimized close-ended questions, interruptions, or leading SMEs to avoid contaminating results. Interviewers received prior training on CTA by experienced colleagues who supervised most interviews.

Data analysis and coding

All interviews were audio-recorded and transcribed verbatim after every interview and analyzed to assess emerging results and to detect data saturation. Transcriptions were then augmented with contents previously identified from relevant textbooks and literature for triangulation.[251-256, 258, 259] Data transcriptions were itemized and thematically analyzed using grounded theory and coded independently by two investigators (BA, AM) by procedural section, cues of situational awareness, critical decisions, and potential pitfalls (issues). Items that were not specific to a single section were marked as "General Concepts". Items were coded into situation awareness (identifying environmental cues and managing accordingly), and decision-making (the cognitive act of exploring and selecting decision paths). Subtasks (action-oriented tasks that lack cognitive components) were isolated to establish a focus on cognitive competencies. The output from this analysis was used to construct a conceptual framework of cognitive competencies to safely perform primary breast augmentation. All quantitative data, including inter-rater agreement, were analyzed using Statistical Package for the Social Sciences (SPSS) v22 (Armonk, NY: IBM Corp), and are reported as median (interquartile range - IQR) and n (%).

6.3 Results

A total of 8 interviews were conducted on six SMEs (Table 6.2). SMEs have a median age of 39.0 (39-65) and 7.00 (6-29) years in independent practice. Most are male (n = 7, 87.5%), perform aesthetic cases in a private setting (n = 7, 87.5%), or are involved in resident teaching 3-5 times per week (n = 5, 62.5%). Half the SMEs have performed more than 250 augmentation procedures (n = 4, 50%). The median duration of interviews was 42.0 (15) minutes, with the longest being 67 and the shortest being 24 minutes.

A framework was created using five rounds of inductive data analysis to identify cognitive expert competence (Figure 6.2). Following reviews, agreement on items after five rounds of inductive analysis was found to be 100% (κ-1.00). A total of 208 items were identified to be involved in primary breast augmentation, with 85 (40.9%) items being related to situational awareness, 123 (59.1%) items to decision-making, and 41 pitfalls.

Five distinct procedural sections were identified (Figure 6.2,3), including "pre-operative planning" (77 items, 1 pitfall), "peri-operative preparation" (32 items, 1 pitfall), "pocket dissection and design" (28 items, 3 pitfalls), "implant handling and insertion" (23 items, 11 pitfalls), and "pocket and skin closure and postoperative care" (13 items, 25 pitfalls). Items not specific to a single section of the procedure were classified as general considerations within one of five main themes (Figure 6.2,3): "anatomical considerations" (9 items), "elements of success" (7 items), "principles of dissection" (9 items), "prospective hemostasis" (4 items), and "indications and limitations of the procedure" (6 items).

6.4 Discussion

Being the most commonly performed cosmetic procedure in the United States,[229] breast-related surgery account for more than a third of all medico-legal claims against plastic surgeons.[264, 265] In fact, plastic surgeons are overall the most targeted surgeons by medical malpractice claims[266, 267], with primary breast augmentation as the most common.[237] Often these claims are related to pitfalls with informed consent and pre-operative planning, poor aesthetic results, and lack of training or expertise as grounds to litigations, rarely technical issues.[266] Thus, as an index procedure in plastic surgery training[11], there is an unmet need to develop novel curricula to address the lack of exposure and confidence among trainees and avoid pitfalls that can lead to adverse events or suboptimal patient-reported outcomes.[11, 15, 197, 231, 232]

Cognitive competencies

Many attempted to define surgical skills that complement a surgeon's technical finesse.[242, 249, 268-270] Collectively, these skills are known as "Cognitive Competencies", but have been also described as "Non-technical skills".[5, 8, 52] These competencies are contained within one of five different domains, namely, situation awareness, decision-making, task management, leadership and communication and teamwork.[243]

Experts in plastic surgery identify and advocate for the teaching of cognitive competencies.[5, 18, 70, 88, 95, 270, 271] The use of CTA for creating educational and assessment tools for multiple surgeries and medical procedures shows benefit over standard learning methods in clinical outcomes.[8, 247, 249] The benefit of this structured method is its effectiveness in structuring knowledge over experts' recall employed in traditional teaching, a skill that can vary between experts.[272, 273] Defining intra-operative decision-making has been a significant challenge and CTAs can assist in developing conceptual frameworks for these competencies. In plastic surgery, CTA-based multimedia programs are effective at teaching surgical decision-making in flexor tendon repair.[18] The use of this tool was also demonstrated in developing "The Burns Suite" (TBS), a pediatric burn resuscitation training scenario.[5] Its use in aesthetic surgery, however, is not yet documented.

Breast augmentation was found to involve 85 (40.9%) items of situational awareness, as opposed to 123 (59.1%) involving decision-making. Of 41 pitfalls identified, all were found to be caused directly or indirectly by the lack of situational awareness at a given step, which was essential for constructing decisions throughout the procedure. Additionally, pitfalls related to breast augmentation also depend on situational awareness in terms of anticipation, prevention and early recognition and recovery from such pitfalls. Such findings are similar to those found in laparoscopic cholecystectomy[244] and to findings from lawsuits mapping most to errors in decision-making.[236, 237, 262]

Prospective error anticipation and prevention

Thirty-five general items (of 208) were found to be involved throughout the procedures, harnessing both situational awareness and decision-making, in one of five themes. Overall, among the five distinct sections of the procedure, situational awareness was mostly involved in the initial phases of the procedure (pre- and perioperative planning, and pocket design), following which the involvement of decision-making increased towards the end of the procedure. Most pitfalls, however, arose during pocket dissection, closure, and the post-operative phase, but were traced to the lack of situational awareness at an earlier stage. A frequently cited example is the concept of intra-operative prospective hemostasis advocated by some experts as an important variable in decreasing the need for adjuncts (drains, regional blocks, etc.), post-operative recovery time, and capsular contracture.[251] The significance of such findings in the building of safe surgical practices is the focus on early error recognition and recovery in training. This has been also noted in mapping causes of litigations to pre and intra-operative errors among 50 cases.[238] Using the results of this study, educational interventions can be developed to include modules aiming to target such concepts, while integrating error prevention, early recognition, and recovery. Teaching complex skillsets requires developing special modules,[249, 269, 274] and are essential in error prevention and enhancing technical skills learning as well.[87, 245, 246]

Pitfalls identified, 41 in total, included pre-, intra-, and postoperative pitfalls, errors, and complications, 25 of which were related to postoperative outcomes. The finding of disfigurement being quoted as claims in 53.1% of litigations need for revision in 42.5%, and scarring in 38.7%, indicate that preventing such pitfalls is essential for competence. As such, the need to address them in training becomes vital in developing competency-based curricula.[237] Interestingly, iatrogenic injuries were found to be least quoted in litigations among 6.5%, and despite their low odds of occurrence, they are critical to prevent in an elective procedure. Deaths, though rare, were mapped to pitfalls with anesthesia, failure in preoperative planning and assessment, and infections.[237] These findings further stress the value of this study, and the ultimate effect training could have on lowering such complications, patient dissatisfaction and litigations in the field of aesthetic surgery.

Competency and shared decision-making

Among other considerations, the success of the procedure, reflecting competency in performance, emerges from seven main items. The most important aspect of success was the awareness of patients' anatomy, and more importantly expectations and goals from the procedure. This was also confirmed by many studies of litigations and stressed upon in many literary sources.[241, 251, 263] Such awareness derives a major sub-section of the pre-operative planning of the procedure, termed as joint or shared decision-making, which involves a bi-directional information exchange between the patient and the surgeon. From one end, the patient shares their preferences and factors, and the surgeon shares their knowledge and expertise on the other, aimed at developing an agreement and a mutual plan that reaches both parties' aspirations. This exercise is essential and common to other medical practices[275] but is of crucial importance in elective surgeries, where patients' expectations can differ and outcomes are largely based on their input.

Lately, this practice termed shared decision-making (SDM), has been emerging in a range of medical and surgical practices, from acute critical care in the emergency room to life/ limb saving procedures, and more applicable to elective aesthetic procedures.[276-278] The population that elective aesthetic procedures serve has special characteristics and preferences that make it harder for a physician to assume a paternalistic approach to care.[276] Ignoring such a concept leads to a lack of awareness of patients' expectations, which are especially unique for each patient. Abandoning such practice leads to unilateral decision-making that does not engage the patient or uninformed consent after having provided insufficient information, which is a recipe for failure, needs for reoperations and medical malpractice.[241, 263, 276, 277] A special cohort of patients exist that are unfamiliar with their expectations and would require assistance, based on years of experience, to derive a medical plan that fits them. On the other end lies a cohort that demands unrealistic and unsafe expectations; meeting such can be disastrous and thus require patient education to avoid complications. Changing years of practice among surgeons to adopt SDM is not simple, but a Cochrane review shows interventions targeting patients and healthcare professionals are effective and are essential with the swarm of options and high-risk for litigations in this field.[238, 241, 265, 267, 276, 279]

Implications of findings within a competency-based education model

Educators in plastic surgery identify the importance of cognitive competencies and advocate for integrating them into post-graduate education.[5, 18, 70, 88, 95, 270, 271] Their importance lies in fast-tracking technical skills training[244] by accelerating the cognitive phase of skill learning and reducing the learner's cognitive load.[88, 280] Also, their introduction creates a culture of error recognition and prevention and increased accountability, thus ensuring competency.[1] This diminishes patient's suffering related to preventable complications, need for re-operations and litigations, most of which relate to errors in decision-making rather than technical errors.[236, 237, 262] CTA exposes skillsets expected to emerge from years of experience and tacit knowledge that are otherwise not readily available to learners within traditional time-based training models. This is because awareness of such skills would be limited to most educators' perceptions or working memory in an educational setting or throughout a scenario intra-operatively.[8, 9, 244, 247]

Based on the presented framework of competencies, a curriculum that is developed to reinforce error recognition and prevention with a focus on situation awareness would have an impact on improving trainee's cognitive skills. The recent advent of part-task simulators, such as the Montreal Augmentation Mammoplasty Operation (MAMO) Simulator and others, focuses on establishing competence through demonstration of technical skills.[67, 281] To complement that, a technology-enhanced learning tool (e-learning) that can be developed using the established cognitive competencies will allow the learner to deliberately practise decision-making. Immersive or experiential learning provides a safe training environment that keeps the used engaged provides room for error commission to transfer the identified competencies through an interactive tool designed specifically for this task. The choice of an e-learning tool emerges from their effectiveness in delivering cognitive skills.[91] The validity of such a teaching model has been demonstrated in multiple fields including thyroid surgery and cholecystectomy.[282, 283]

Limitations and future work

This is the first study employing CTA in aesthetic surgery, specifically on cognitive competencies.[5, 18, 70, 95] With the shift in surgical training to a competency-based model, the findings of this study are essential in establishing measured and objective competencies.[1, 2, 8, 21] This work is a primer to define cognitive competencies in breast augmentation as a model for aesthetic surgery. Further work would aim to explore methods to teach and assess these competencies and provide validity evidence for their effectiveness.

Inherent limitations of such analysis include the qualitative nature of the data and the semi-structured approach to data collection, leading to the possible inconsistency of data. To address such limitations, multiple literary sources, intra-operative observations, and interviews with a range of experts were used. Additionally, raw data were reviewed and developed using inductive analysis through two independent reviewers, increasing the reliability of the results. Clinical relevance and effectiveness of this methodology are yet to be demonstrated through the application of these findings. Moreover, the wide range of techniques utilized by surgeons around the world, controversies, and non-evidence-based clinical practices presents an obstacle for developing a single comprehensive framework. This issue was addressed by targeting experts of different demographics and backgrounds.

6.5 Conclusions

This qualitative study defines a framework for the various cognitive processes required to perform breast augmentation along with possible pitfalls that can arise with such a procedure. The data from this study can be used to develop interventions aimed to teach and assess these competencies to enhance surgical training, improve performance and avoid pitfalls.

7. Cognitive Competencies and Their Role in Surgery

In 1956, Benjamin Bloom was the chair of a committee of educators that developed a taxonomy for educational objectives of three main domains, namely, cognitive, affective and psychomotor.[34] For each of the domains, the educational objectives are arranged into logically flowing levels of learning objectives that are ordered by the amount of processing involved (lowest to highest). This taxonomy of learning objectives is the most widely used with multiple revisions and brought on the foundations for many educators aiming to provide a holistic approach to developing educational interventions that targeted multiple domains together. The "Cognitive" domain is the focus of this matter which is arranged into six levels with multiple "verbs" associated with each level. The lowest order level is knowledge (to remember facts and concepts), followed by comprehension (to demonstrate an understanding of such facts and concepts), application (to apply such knowledge and understanding to solve problems), and lastly analysis (to examine the available evidence and apply learnt concepts), synthesis (to create new patterns or solutions) and evaluation (to judge about given solutions based on available criteria) at a single level. Within this domain, surgical cognitive competencies encompass all levels of learning, but higher-order mental functions are more involved in reaching of such competencies (analysis, synthesis, and evaluation).[268, 269, 284] As such, clinical reasoning and judgement in surgery, a part of cognitive competencies, can be identified as a complex task that requires special methods for teaching and assessing, particularly when an expert level of competence is to be reached.[249, 269, 274]

Decision-making plays a major role in the outcomes of surgery and is viewed as the most important factor in a competent surgeon.[10, 240] Spencer is famously quoted for relating three-fourth of surgical competency and consequently success to competency in decision-making with the fourth relaying on surgeons' technical competence.[285] Multiple efforts using theory-based approaches have verified the validity of such claims, and most demonstrated that the impact of such decisions on error prevention is more significant than technical errors along the stream of surgical management.[242, 244-246, 249, 268, 286] For instance, of 75 errors identified through the interview of expert surgeons in laparoscopic cholecystectomy, 32% were found to relate to situation awareness and 65% to decision-making, with 81% being related to either.[244] Having said that, cognitive competencies should be a very important aspect of competency training and should be integrated into training on technical skills, which seems to be otherwise the focus of most available educational interventions.[249] Additionally, currently available interventions and teaching models are described as being subjective and biased in terms of assessment and teaching of cognitive competencies by many authors, and only a few align with the transition to competency-based education.[9, 243, 244] Educating trainees on concepts and tasks deemed essential for forward planning, error prevention and detection, and associated decision-making and integrating such skills to technical training will help in error prevention.[242, 245, 246] Such integration was found to increase the effectiveness of teaching technical skills in terms of educational outcomes as compared to technical skills on their own.[4, 87, 287]

A better demonstration of the effect of such integration can be achieved through the understanding of the stages of skills' learning model postulated by Fitts and Posner.[280] Although many other models exist, they are less popular and don't account for the effect of cognition on the process of skill learning.[288] Skills can be learnt in three phases based on this model, cognitive, associative, and autonomous. The cognitive stage involves the majority of cognitive activity and allows for establishing the appropriate mindset necessary for performing the task in hand or achieving a given skill with minimal to no practice of the skill, and is associated with inefficiency, inconsistency and lack of fluidity of movements. This involves knowledge and understanding of the task, which is an essential prerequisite for the next stage that concentrates on associating specific input to appropriate responses (cognitive set) with less involvement of cognition, but conscious control of movement and minimal atomicity. Lastly, learning shifts to an indefinite improvement of skill set through routine or repetitive practice and feedback that involves little to no cognition, and is characterized by efficient, fluid, automatic and accurate motion. The developers of this model stress on this being a continuous learning process that develops into employing further stages. Evidence can be also extrapolated from non-randomized and randomized trials on skill learning suggesting that cognitive learning is not only essential for the knowledge and understanding of the task, but also for learning and improving the technical aspects of performing it.[87, 245]

Many attempts have been made to defining decision-making within the field of surgical expertise and some specifically focused on decisions made intra-operatively.[249, 268-270] Collectively, these skills are known as "Cognitive Competencies", have been also described as "Non-technical skills".[5, 8, 52] In an attempt to gather a consensus of experts on the definition of decision-making in surgery, a qualitative free text web-based survey was performed by Rennie et al. among experts in surgery, cognitive research and medical education.[268] The study identified twelve overlapping features of good decisions and decision-makers and proposed a working definition of a good decision maker that can help teach and assess decision-making skills and quality of decisions. The authors of this paper state based on their results that "A good surgical decision-maker is a surgeon or trainee who makes well informed and considered, timely, patient-focused decisions which are backed by sound knowledge and appropriate evidence base, while recognizing their limitations, the need for collaboration, reflection and clear communication to bring about an appropriate action".[268] Despite this working definition, many authors have attempted to develop frameworks to explain and encompass cognitive skills in surgery, as well as to understand the process and role that surgeons assume while making decisions in various contexts.[242-244, 249, 274, 289] This group of cognitive and interpersonal skills (non-technical skills) were found to be contained within one of five different categories, namely, situation awareness, decision-making, task management, leadership and communication and teamwork.[243] Two components of a particular focus in this work are decision-making and situation awareness. Situation awareness is composed of gathering and understanding of the environmental cues (information) and projecting and anticipating future states based on such cues. Decision-making, on the other hand, entails exploring available options at a given decision point, and communicating and reviewing such decisions.[243] In a review of the hand questions on the plastic surgery in-service training exam, for six years (2008 to 2013) consecutively, this was found to be the most commonly tested on a taxonomy of questions with 60.5% of the questions throughout the years.[290]

Despite the available evidence on surgeons' cognitive processing and cognitive competencies and methods to teach and assess such competencies, this field is still developing, and as will be later demonstrated, little or no evidence is available within the specialty of plastic surgery, and more importantly in aesthetic surgery. Despite this, experts in plastic surgery identify and advocate for the teaching of these competencies.[5, 18, 70, 95, 270, 271] Efforts from several experts to develop educational models to teach and assess cognitive competencies in the field of plastic surgery exist, but not in aesthetic surgery.[5, 18, 70, 95] Using cognitive research methods, such as cognitive task analysis, our understanding of the process of expert decision-making in the field of plastic surgery can be further enhanced to aid in the creation of educational and assessment tools that can ensure such expert competence can be passed on to trainees in this field.[8, 9, 247] Another aim of the presented work is to conduct such an analysis using Breast Augmentation surgery as a model of a procedure in aesthetic surgery to define cognitive competencies in this procedure. Through this analysis, a comparative examination of the process of decision-making in aesthetic surgery in particular, and plastic surgery in general, will allow for contrast to other mental models available in the literature, and thereby suggestion of frameworks that will help educators design interventions to teach and assess such competencies in this field.

8. Teaching and Assessing Cognitive Competencies in Aesthetic and Plastic Surgery

Becher Al-halabi[1,2], Melina Vassiliou[2], Mirko Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, QC, Canada.
2. Department of Surgery, McGill University Health Centre, Montreal, Quebec, Canada

8.1 Introduction

Current models of plastic surgery teaching, composed of time-based rotations, vary in surgical exposure and lack objective assessment of competence.[1, 2] Governing post-graduate educational bodies are transitioning to a competency-based model that provides an objective assessment of competence to address such issues.[1-3, 12] This is of special importance in aesthetic surgery, given the elective nature of involved procedures.[1, 11, 15, 16] Plastic surgery educators internationally attempted to address deficits in exposure and assess competence but most targeted technical skills only with limited success, applicability and competency-assessment.[1, 3, 5, 17-19]

Surgical competencies encompass all domains of learning as per Bloom's classification, but higher-order mental functions are involved in surgical care decisions.[34, 268, 269, 284] Clinical reasoning and judgment, a part of cognitive competencies in surgery, are complex tasks that require special methods for teaching and are difficult to measure.[249, 269, 274] These are decisive in surgery and require careful design of interventions aimed at such competencies.[10, 240, 249, 269, 274, 285] Their impact on error prevention is more significant than technical errors, demonstrated by many cognitive and litigation studies.[238, 241, 244-246, 249, 263, 268, 286] Furthermore, their teaching accelerates and increase the effectiveness of teaching technical skills [4, 87, 245, 246, 287]

This qualitative study aims to establish a framework for educational curricula that teach and assess cognitive competencies in plastic surgery using mental models of two distinct plastic surgery procedures.

8.2 Methods

Data collection

Data used included literary sources and manuscripts from cognitive task analysis (CTA) interviews of two procedures, primary breast augmentation and flexor tendon repair (Figure 8.1). The choice of such procedures was based on the elective and emergency nature of these operations, respectively, and the availability of data for analysis. CTA interview templates were used to aid subject-matter experts in thought processes expression of decision-making involved in patient care in these two procedures. After obtaining informed consent from subject matter experts (SMEs), semi-structured interviews were performed, and audio recorded at two institutions to obtain raw qualitative data. SMEs were randomly sampled to represent various demographic and training backgrounds. Interviewers attempted to minimize close-ended questions, interrupting, or leading the SMEs to avoid biasing the results.

Data analysis and processing

Interview recordings were transcribed verbatim and augmented with content from the literature, including textbooks, journal articles, and field observations to develop a concise coverage of advanced cognitive processes involved in patient care (Table 8.1). Due to differences in the methodology of the CTA interviews used for either procedure, the raw data were re-analyzed de-novo for this study. The focus of the qualitative analysis was on the higher-order subconscious and automated functions of decision-making, pattern recognition, and situational awareness that experts employed throughout patient care. The data of each of the procedures were then itemized and thematically analyzed and coded by two reviewers into decisions and logical elements of decision-making with any difference resolved through a discussion until an agreement was met.

Mental models and framework development

Itemized data were converted into logical nodes and a computer-based fuzzy-logic cognitive mapping software, mental modeller[291], was utilized to model relationships between nodes. Representation of effect was done using positive (blue) or negative (red) relationships with varying strengths (line thickness). Influence diagrams represent the relationship between various logical elements, decisions they affect, pitfalls, and outcomes. Such methodology has been previously used to improve communication and understanding of decision-making.[292-294]

Similarly, the models created were used to compare reasoning in the reconstructive and aesthetic settings of plastic surgery using two index procedures. A framework was created using results and literary sources to introduce and better understand cognitive competencies in plastic surgery and guide their teaching and assessment.

8.3 Results

Two separate mental models were produced to characterize the mental processes involved in either procedure (Figure 8.2,3). A qualitative analysis of the mental processes modelled from expert interviews for primary breast augmentation and flexor tendon repair displays multiple similarities and differences in the process of decision-making.

A review of the current models on surgical decision-making and reasoning was reflected in this qualitative analysis of the models of the two procedures to identify employed reasoning methods (Table 8.2). Literature was then used to identify five different categories of cognitive competencies, situation awareness, decision-making, task management, leadership and communication and teamwork. Decision-making was further divided into various methods of reasoning. A generic mental model for surgical care was then adapted to provide a framework for teaching and assessing cognitive competencies within the model (Figure 8.4). A qualitative review of the reported methods of the teaching and assessment for each cognitive competency was performed (Table 8.3).

8.4 Discussion

The “Cognitive” domain[34] of learning in surgery encompasses higher-order mental functions.[268, 269, 284] As such, it requires special methods for teaching and assessment to ensure a high level of competence within the framework of competency-based education.[249, 269, 274] Breast augmentation is an index aesthetic procedure that is commonly performed by plastic surgeons.[11, 229] Decisions affect outcomes in breast augmentation evident from studies of malpractice suits.[233-239] Thus, addressing decision-making is important in building competent plastic surgeons.[10, 240] Flexor tendon repair, another end of the plastic surgical spectrum, can model non-elective surgeries as hand injuries can be debilitating if complicated by low-quality repair.[295-298] Although multiple training models have been developed to provide objective feedback in terms of tendon purchase and confidence, a CTA-based multimedia curriculum of decision-making in the repair of zones I and II demonstrated significant improvements in knowledge in comparison to traditional learning methods.[18, 60, 136]

Using CTA, the process of expert decision-making and involved tacit knowledge can be identified to define cognitive competence.[8, 9, 247] Data from CTA of primary breast augmentation and flexor tendon repair can be used to model mental processes involved in the decision-making of these procedures. The tacit knowledge and processes that experts use to produce decisions in surgical care can be exhibited by mental models.[292] Based on qualitative data, these have been used to explore decision-making in complex high-risk procedures, improve patient implant selection, and other contexts of injury prevention and risk communication.[292-294, 299] Thus, similarly designed mental models can assist in the understanding of mental processes in plastic surgery and develop interventions aimed at teaching and assessing them.

Defining cognitive competencies within plastic surgery education

The focus of the decision-making literature in surgery is limited to intra-operative decisions and what constitutes competent decision-makers in surgery.[249, 268-270] Collectively, “Cognitive Competencies”, or “Non-technical skills”, are a constellation of perceptive and interpersonal skills employed throughout patient care.[5, 8, 52] Experts were surveyed and showed consensus on the need for establishing knowledge base, recognition of own limitations (meta-cognition), collaboration, and effective communication for competency in surgery.[268] Other attempts to define cognitive skills in surgery and understand involved processes exist in various contexts.[243, 244, 249, 274, 289] Most experts identify cognitive competency in surgery within five categories, situation awareness, decision-making, task management, leadership and communication and teamwork.[242, 243]

Situation awareness is the act of gathering external and internal cues to anticipate future states. Decision-making entails exploring options at a checkpoint and communicating, implementing and reviewing such decisions.[243] Between these two competencies, two forms of clinical thinking arise, reasoning and deliberation. While reasoning in surgery applies a complex clinical scenario into a technical one where a set of rules are applicable, such as guidelines, deliberation individualizes clinical scenarios to apply situation awareness of each setting, the surgeon’s professional judgment and case-based variables to develop a solution.[269] Deliberation thus proves useful in critical scenarios as it combines both competencies.[300] This highlights the importance of deliberate training and practice during surgical training. Moreover, task management is to plan and flex around changes; leadership is setting standards to others and supporting them and coping with a pressured environment.[243] Lastly, communication and teamwork involve the exchange of information to construct a shared understanding and coordinate tasks among team members.[243, 300]

Intra-operative competence assessment using CTAs identifies five central themes reflective of the aforementioned competencies, namely psychomotor skills, declarative knowledge, advanced cognitive skills, interpersonal skills and personal resource skills.[242] Advanced cognitive skills, of interest to this work, are tacit knowledge and cognitive processes that aim to remove a pathology, restore physiology, or to alter anatomy to a more natural state. In an expected state of operation, an automatized process involves planning, error prevention, and risk reduction. Once deviated, error recognition, rescue and recovery are activated.[242] Thus, training on such competencies, most importantly advanced cognitive skills, is paramount to improve safety in surgery as it allows the organization and rapid access to these cognitive processes.

In the field of plastic surgery, little to no research exists to what constitutes cognitive competencies in plastic surgery. Interventions targeting cognitive competencies in plastic surgery exist.[5, 18, 70, 95] Rohrich demonstrates the importance of critical thinking taught in conferences in the learning process for residents in reaching optimal solutions for complex problems, citing the Socratic method of deductive reasoning.[270] A recent editorial focused on surgical judgment in plastic surgery within the models of rehearsal and “slowing down” based on initiators that lead to cognitive recruitment to tweak operative plans.[88] The authors advocated its teaching through peri-operative briefing and debriefing, simulation, mortality and morbidity meetings, and residents-run clinics. Script concordance testing to assess surgical judgment has been proposed as well.

Comparison of mental models of two procedures in plastic surgery (elective vs. emergent)

Three decades of research on cognition in surgery revealed several models surgeons use in their care.[274, 300] Reasoning is a complex mental process that lies on a cognitive-load continuum, which can take the form of recognition-primed, rule-based in non-complex scenarios, or analytical. The first is a subconscious process that is frequently employed by experts whereas the latter is the highest cognitive demand frequently employed by non-experts.[274, 289, 300] By employing recognition-primed reasoning, the surgeon can offload their cognitive load and improve their perception and thought process. Another aspect of decision-making is the contextual objective, for instance, pre- and post-operative (diagnosing and managing deviations from normal), peri-operative (preparing for a procedure), and intra-operative (prospective planning and re-assessment of findings).[274] Surgical judgment can also be described by style or method employed, namely, clinical reasoning or deliberation (practical reasoning).[300]

Clinical reasoning employs methods such as hypothetic-deductive (hypothesis-driven investigation), diagnostic, interactive (multi-disciplinary), and narrative (representation) reasoning. On the other hand, predictive (experience), intuitive (creative), collaborative (shared with the patient), teaching, pragmatic (realistic), and ethical (moral) reasoning are employed in deliberation or practical reasoning. A mix of these methods forms a continuum of three decision processes: personal professional judgment, practical wisdom, and professional judgment. The use of personal professional judgment considers experience to affect interaction with a complex problem, combining rule-based and analytical decision-making. Practical wisdom assumes moral virtue into decisions and allows a surgeon to deviate from common "rule-based" decisions to a "good" for the patient. Lastly, professional judgment is the outcome of analytic decision-making affected by practical wisdom, resembling recognition-primed decisions. Reflecting these methods onto the two procedures (breast augmentation and flexor tendon repair) allows a comparison between the methods experts employ in either procedure.

Pre-operatively, a combined diagnostic and interactive reasoning to detect the presenting problem and to gather expectations is noted in an elective setting. Following that is a combination of predictive (based on experience), collaborative (shared decision-making), and ethical reasoning is employed to determine the indications and plans for adjunct procedures. Marking is important in planning to guide intra-operative steps through recognition-primed decisions as opposed to marking done in reconstruction that follows a rule-based manner for exposure or harvesting a flap. An analytical approach is utilized in both settings for pre-operative health optimization. In a reconstructive setting, however, diagnostic reasoning and rule-based decision-making determine the urgency (digit salvage), as compared to a pragmatic intuitive procedure tailored to the patient's current occupational and health status and presentation. It is also noted that collaborative reasoning carries more weight in an elective setting (shared decision-making). This is affected by recognition-primed decisions to design the pocket and to choose the implant based on individualized patient measurements. Post-operatively, a combined diagnostic and recognition-primed decision-making approach is employed in both settings.

Intra-operatively, as with every procedure, essential steps are outlined by experts along with adjunct steps required to achieve intra-operative goals. Unlike an elective setting, with a pre-established site and the number of incisions, an intuitive form of reasoning is involved in a reconstructive setting second to the uncertainty that both the surgeon and patient are made aware of. In either surgery, a recognition-primed approach is assumed to detect and prevent intra-operative pitfalls, with an analytical rule-based approach assumed in error recovery and development of a contingency plan to manage a given error.

Teaching and assessing cognitive competencies in plastic surgery

Given the contrasts noted in reasoning employed to reach clinical decisions in either procedure, identifying mental processes is vital to develop effective teaching and assessment interventions targeting competency. In this study, a classification of five different cognitive competencies that were extracted from CTAs from surgeons of multiple specialties was used.[243]

The teaching of situation awareness, the ability to gather, assimilate and project cues,[243] can be achieved through direct surgeon-learner interactions demonstrating and critiquing observations and assumptions made by learning to explore and assess their knowledge base, self-evaluation, ability to perceive and evaluate risks and to anticipate errors and complications.[52, 242, 243, 269] Use of computer-based simulation (CBS), such as virtual patients (VP) and virtual reality (VR) and MCQs are recommended media.[90] Besides, exercises such as narrative reasoning with trainees as in mortality and morbidity meetings are advocated to reinforce self-evaluation (meta-cognition).[88, 269, 300] For instance, a simple art course for plastic surgeons improved trainees' proportions judgment, ability to record deformities and surgical planning.[104]

Decision-making is a cognitive continuum of clinical reasoning, deliberation, personal professional judgment, practical wisdom, and professional judgment often variably employed.[269] Testing of this domain involves exploring the questions posed trainees to reach reasoning, factors affecting such reasoning and the role their knowledge base played in eliciting decisions. Additionally, assessment of the ability to justify decisions, confidence in a decision, as well as characterization of decisions relative to experts is important as experts' opinions often vary. The teaching of clinical reasoning (rule-based) involves learners' expression of opinion and process leading to reasoning. This can be achieved through simulated clinical immersion (SCI), use of VP (or other CBS platforms), and MCQs.[90] An applicative example is the "burns suite", an immersive simulation environment of pediatric burn resuscitation.[5] Deliberation (Analytical), another type of reasoning that focuses on technical variables can be demonstrated using SCI, in-situ learning, or the use of CBS.[90, 269] Two examples include CTA-based teaching for flexor tendon repair[18] and the use of virtual surgery.[70] Moreover, personal professional judgment can be learnt through personal narratives of thought process achieved through SCI, in-situ training, professional meetings, or rounds.[90, 269, 300] Practical wisdom (virtue-based), on the other hand, focuses on non-technical variables such as moral values[269] and can be demonstrated through SCI or CBS; a practical example is residents-run clinics.[269, 301, 302] Lastly, professional judgment combines the above processes and thus can differentiate competency in an effortless decision in a holistic approach seen in resident-run clinics.[301, 302]

Task management teaching involves the proposal of an action plan with critique from educators in an individualized patient context while assessing flexibility to change, identifying overall care goals, and developing contingency plans in cases of errors.[242, 243, 269] A good medium for learning and testing is through SCI, in-situ learning, CBS,[90] or residents-run clinics.[154, 301, 302] Leadership is a distinct competency that is often absent from educational interventions and involves learners' ability to set and maintain standards of care while supporting team members; it signifies stress management, recognition and use of personal and environmental resources, and respect for hierarchy.[242, 243] A Demonstration through in-situ or in simulated environments can be achieved through SCI or scenarios such as organizing rounds, operation or call schedules.[300] Resident run clinics and 360° rotation evaluations are similarly practical to test leadership.[301-303] Lastly, and least assessed is communication and teamwork, which involves the ability to exchange information and establishing a shared understanding to allow team co-ordination.[242, 243, 300] Interpersonal skills are often assessed in-situ or in simulated environments (SP, SCI), such as the exercise of surgical timeouts peri-operatively, exercising informed consents, or disclosing bad news or errors post-operatively.[242, 243, 300] For this, the use of 360° evaluations, resident-run clinics, and combined curricula aimed to target such competency are likewise effective.[168, 301-303]

From theory to practice

“As to surgery, surgeons are made, not born.”, and like technical skills, cognitive competencies require deliberate practice and targeted teaching.[304] Experts recognized in the past what we can define now of the importance of nurturing surgeons’ ability to reason (decision-making) and to observe and record observations (situation awareness).[88] This does not only offload the Surgeon’s cognitive capacity for further processing but also allows the acceleration of technical skills acquisition.[8, 245, 272, 305] The focus on cognitive competencies should not be limited to complex surgery but the effect lack thereof has on patient morbidity.[10, 240, 249, 269, 274, 285] Distinctive cognitive competency domains have been established along with core competencies common to various surgical specialties.[52, 242, 243]

Limitations, and further work

The authors can identify inherent limitations to this study in terms of design and data collection, and heterogeneity of experts that can affect the quality of the data. However, no major differences in standards of care were noted and the data used was re-analyzed de -novo to account for such differences. Future research to create and demonstrate the effectiveness of interventions targeting cognitive competencies on trainee’s self-confidence, psychometrics, clinical performance, complications and patient satisfaction.[35]

8.5 Conclusions

Considering international shifts to competency-based surgical education and lack of educational and assessment tools that establish competency in plastic surgery calls for validity evidence on the effectiveness of CMBE in plastic surgery and improved the practical definition of milestones leading to competency; much research and development in plastic surgery education is required.[1, 24, 174, 230, 306] In this study, we attempt to introduce cognitive competencies using two models of distinct procedures in plastic surgery and provide educators with a priming framework for teaching and assessing such competencies in plastic surgery. The practicality and effectiveness of teaching such competencies are theoretically established but are yet to be well demonstrated.[244]

9. Assessment of Cognitive Competencies in Plastic Surgery

Following the development of the tools, they can be implemented, and further validated and tested on both learners and educators to demonstrate their effectiveness in plastic surgery. Metrics identified through task analysis or the analysis of expert performance may be used to improve and expand the virtual patient cases.[284] These metrics can be analyzed for face validity by comparing the performance of learners and experts, amongst other domains of validity.[37-39] Pilot testing of the virtual patients initially before testing should be done to avoid technical errors and distracting flaws in the design. Educators can also gather usability metrics through questionnaires used to survey the opinion and attitudes of both learners and educators towards the use of such methods as educational and assessment tools.[35, 307, 308] Data from such usability surveys will help assess such tools for further use and gather any feedback for improvement.

In terms of assessments, benchmarks defined for expert decision-making based on patterns of decisions and metrics gathered from experts can be used to trace trainee's performance. Although this is a new approach to education in aesthetic plastic surgery, it has been previously demonstrated in reconstructive surgery (tendon repair)[18] and various other procedures in general surgery and intensive care.[8] If the tools developed were found to be valid, such tools can be integrated with a physical part-task simulator. Additionally, similar methods can be replicated to develop curricula that involved multiple other surgeries in aesthetic plastic surgery, and other disciplines of plastic surgery. The development of valid educational and assessment tools based on these decision points will help the initialization of the change of the teachings in plastic surgery into competency-based tools and curricula.[1, 52]

Assessment of skills in plastic surgery was attempted by Stranc through expert subjective assessment of videotaped surgical performance on planning, dexterity, movement efficiency, and communication and concentration, which allows for self-assessment and aids in learning.[309] Assessment of video-taped basic tasks, skin suturing, medium-thickness skin graft harvesting, and tendon repair on bench-based models, was also attempted to measure skills, and validated by demonstrating difference based on the level of experience and reliability of assessment of surgical skills using the objective structured assessment of technical skills (OSATS) tool.[310] Similarly, another rating tool for surgical instruments compared skill in the closure of three, 3 cm long incisions in different techniques between first-year residents at the beginning and the end of their year.[94] This tool assessed video-recorded tasks using a scale composed of 17 points of competency and a 5-point scale of global performance, demonstrating the difference between two groups and high validity in internal structure. Global evaluations using 360-degrees evaluations based on staff (surgeons, nurses and staff) have been used to assess residents in all ACGME competencies, with reports of difference in rating of professionals in two distinct clusters.[303]

Multiple scoring systems in surgery were developed for non-technical skills with various focuses on elements surrounding a similar taxonomy of situation awareness, decision-making, task management, leadership and communication and teamwork.[242, 243, 311, 312] One of the most commonly studied tools is the non-technical skills for surgeons (NOTSS) that were demonstrated to be accurate and valid with good inter-rater reliability.[312-316] Another notable scale is the surgical decision-making rating scale (SDMRS), a scenario-based surgical judgement rating scale developed in Canada that tests anatomic recognition, current task management, immediate surgical planning, avoidance of complications, and higher-level planning.[317, 318] Given the variability in the available tools and the competencies targeted for each procedure, educators should take the objectives of assessment into account.[311, 312]

10. Improving Cognitive Competencies in Breast Augmentation - A Self-Controlled Trial

Becher Al-halabi[1,2], Jessica Hazan[1], Nayif Alnaif[1], Melina Vassiliou[2], Mirko Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, QC, Canada.
2. Department of Surgery, McGill University Health Centre, Montreal, Quebec, Canada

10.1 Introduction

The transition from time-based rotations with variable exposure and lack of objective assessment of aptitude into a competency-based model calls for tools that address these issues.[1-3, 12] This is of special importance in aesthetic surgery, given the elective nature of the procedures.[1, 11, 15, 16] Efforts to demonstrate competence, however, mainly targeted technical skills with limited success and applicability.[1, 3, 5, 17-19] Surgical competencies encompass all domains of learning, but expert cognitive competence involves higher-order mental functions.[34, 268, 269, 284] Clinical reasoning and judgment are complex tasks that require special methods for teaching and are difficult to measure.[249, 269, 274] Teaching clinical reasoning improves judgement and consequently prevents errors and accelerates technical skills acquisition by reducing the learner's cognitive load.[4, 87, 238, 241, 244-246, 249, 263, 268, 286, 287]

Breast augmentation is a procedure commonly performed by plastic surgeons where intra-operative decision-making is essential in optimizing outcomes and avoiding litigations.[11, 229, 233-239] The technique of cognitive task analysis (CTA) can be used to delineate the process of expert decision-making as well as to identify key CCs.[8, 9, 247] Multiple CTA-based training models have demonstrated significant improvements in knowledge in comparison to traditional learning methods.[18, 60, 136] Similarly, CTA-based curricula have demonstrated improvement in technical skills in various domains.[8, 9, 273, 305, 319, 320] However, the use of CTA-based curricula has been limited in aesthetic surgery.

This self-controlled trial employs a CTA-based curriculum to teach and assess CC's in breast augmentation surgery. By demonstrating the ability to define, transfer, and assess CC, similar models can be applied to other procedures. This is essential to augment currently available curricula to encompass all aspects of plastic surgery and further improve our understanding and assessment of surgical competence.

10.2 Methods

Instructional design

A systematic and theory-driven approach was used to identify CC in breast augmentation through CTA.[8, 248-250] Semi-structured CTA interviews were designed based on Delphi-panel[11] task analysis and guided by textbooks,[251-253] litigation studies,[236-239] and the literature.[241, 254-263] Case-based CTA interviews with 20 different cognitive probes (Table 6.1) were used to elicit experts' cognitive processing. Interviews were audio-recorded, transcribed and analyzed to synthesize 208 cognitive items and 41 surgical and aesthetic complications used for curriculum design. The Curriculum was composed of five main themes that were translated into 5 different modules on an interactive web-based multi-media enriched platform (Figure 10.1). The modules, pre-operative preparation, surgical judgement, implant selection, safety and complications, and surgical perception, were designed to cover the breadth of the procedure and the items of the CTA. These online modules were piloted on a few medical students (n=5) and plastic surgeons (n=2) and reviewed for content, ease of use, clarity of graphics and multi-media and technical bugs before deployment to transfer CC to learners.

Participant selection and knowledge transfer

A systematic approach was employed to test CC involved in breast augmentation by performing CTA as aforementioned (Figure 10.2). Plastic surgery residents from different levels of two programs were invited to participate in this study. The invitation discussed the aims of the study and focus on cognitive skills. Consenting participants were surveyed on self-perception and the importance of these skills relative to others. All participants were asked to prepare for two weeks using their usual study materials for a board-exam-style assessment on primary breast augmentation (PBA) after which they underwent a pre-test. This control phase was followed by exposure to the CTA-based learning modules for two weeks (the intervention) and a post-test thereafter. During the pre-test, participants were asked to report the study hours per day dedicated to this study (control) which averaged a total of 8.2 (6-12) hours and 5 hours were required to complete the CTA-based curriculum (intervention). Participants were asked to avoid exposure to any other resources during the second part of the study and not to seek answers to the interviews to avoid contamination.

Participant assessment

Knowledge assessment involved 20 randomized, validated multiple-choice-questions (MCQs) as a pre-test and 20 different MCQs as a post-test. CCs were assessed using semi-structured interviews after de-briefing on the interview process and presented with 20 cognitive probes to elicit discussion. Participants were encouraged to ask for cues, to freely discuss their decisions, and to debrief on which cues led to a decision. Interviewers received training on CTA and minimized asking close-ended questions, interrupting, or leading the participants to avoid contaminating the results. The interviews were audio-recorded, transcribed verbatim, itemized, anonymized and scored by two different blind assessors using the non-technical skills for surgeons (NOTSS), the surgical decision-making rating scale (SDMRS) and a CTA-based procedure-specific score (PSS) created de-novo for this study.

NOTSS is a validated behavioural rating scale that was developed by the royal college of surgeons of Edinburgh and the national health service (NHS) education for Scotland and repeatedly studied.[86, 243, 312, 316, 321] Of the skills taxonomy of the scale, situational awareness, decision-making, communication and teamwork were applicable and assessed based on NOTSS handbook.[316] Rating for the NOTSS was re-coded to ease comparison into 5 (good), 4 (acceptable), 3 (marginal), 2 (poor), and N/A – 1 (was not used for coding) with a maximum score of 5 per element with a composite of 15. SDMRS is a scenario-based surgical judgement rating scale developed in Canada that tests anatomic recognition, current task management, immediate surgical planning, avoidance of complications, and higher-level planning.[317, 318] The scale uses a linear ascending score of 1-5 (highest) for each element with a composite score of 25. Lastly, CTA results from experts were used to design a PSS with a focus on pre-operative, key decisions, peri-operative, intra-operative, recovery room issues, and post-operative care. The scores of each sub-component for the elements (Table 10.1) were then averaged to a maximum score of 5 per item with a composite score of 35. The rating-scale used specifically for this assessment focused on mentioning cues (recall and awareness), the ability to explain reasoning (decision-making), and the need for prompting by the interviewer.

10.3 Results

A total of 18 residents were recruited to the study, of which 10 Junior (PGY 1-3) and 5 Senior (PGY 4-5) completed all components of learning and testing (Table 10.2). Residents reported low confidence and comfort in performing PBA with low exposure rates in terms of procedures performed. Participants perceived all skill domains equivalently important, with less importance put on cognitive and affective skills. In general, senior residents displayed higher confidence and comfort level with greater exposure to the procedure.

Knowledge assessment scores (MCQs) were higher for senior residents, who were exposed to a higher number of breast augmentations, than juniors in pre and post-tests. These scores improved for both groups before and after the intervention. The average interview duration was 36.6 and 42.5 minutes for the pre-test and post-test. A total of 38 CTA-interviews were included in the analysis, comprising of 15 residents (pre and post) and 8 experts. Overall, all participants showed significant improvement in PSS, SDMRS, NOTSS following the intervention (Table 10.3, Figures 10.3-5). This was true for both senior and junior residents, with higher scores for experts.

The PSS scores were higher for seniors than juniors in all subsets with improvements following the intervention. This improvement was more significant in the senior group but was less prominent in the recovery room issues. Overall, expert scores were higher than the final scores at 33.9/35 for the overall scored, compared to 24.4 and 27.2 for junior and senior post-test scores, respectively. A similar trend was noted for the SDMRS, with higher scores for seniors than juniors, and improving following the intervention but not reaching those of experts. This was true for all subset scores as well with significant improvement in complication avoidance and higher-level planning. The final scores were again higher for experts (24.2/25), compared to 17.4 and 15.9 for junior and senior post-test scores, respectively. Lastly, categorical NOTSS scores were similar post-test for juniors and seniors in terms of a composite score with 10.4 and 10.8, respectively. There was no significant pre/post-test difference in communication and teamwork. The most significant improvement following the intervention was in situational awareness among junior residents with less significant improvement among senior residents.

Table 10.4 shows the correlation between different assessment scores and level of experience (PGY years). The correlation between PSS and SDMRS and NOTSS was significantly high (>0.7), as well as with experience level and knowledge score (MCQ). In terms of NOTSS and

SDMRS, a high correlation was noticed between the scores and level of experience. Knowledge score had a low (<0.3) correlation with PGY years but moderate to high correlation with other scores. When examining the PSS for reliability, the Cronbach's alpha was 0.963 between domains and 0.979 across all scores. Interclass-correlation (ICC) moderate for each rater (0.574) and high for both raters (0.977).

10.4 Discussion

The "cognitive" domain of surgical education encompasses higher-order mental processes and requires alternative methods of skills acquisition and assessment.[34, 249, 269, 274] Decision-making and other CCs are important in implant selection, injury prevention and risk communication.[292-294, 299] Cognitive Competencies, or "Non-technical skills", are a skillset of perceptive and interpersonal skills that experts use in surgical care and identify them as knowledge, recognition of the environment and own limitations (meta-cognition), collaboration, and communication.[5, 8, 52, 268] Cognitive skills can also vary depending on the context of the procedure.[243, 244, 249, 274, 289] However, five main domains classify cognitive competencies: situation awareness, decision-making, task management, leadership and communication and teamwork.[242, 243]

Situation awareness allows gathering cues (external/internal) to anticipate future states, while decision-making explores options given the cues and communicating, implementing and reviewing (prospectively/retrospectively) such decisions.[243] These two competencies constitute the fundamentals for surgeons' reasoning and deliberation in critical scenarios making them essential.[269, 300] Task management is to plan and flex around changes, while leadership is setting standards to others, supporting them and coping with a pressured environment.[243] Lastly, communication and teamwork involve the exchange of information to construct a shared understanding and coordinate tasks among team members.[243, 300] Previous CTAs of different procedures in surgery, including work by the authors, identify common themes that reflect these domains.[242, 243, 272, 273, 320] A component surgeon's thought process is automatized through planning, error prevention, and risk reduction while employing CC. If the clinical course deviates, CCs allow error recognition, rescue and recovery to be automatically activated.[242] CCs not only offload the surgeon's cognitive capacity to allow the processing of more external cues but also accelerate their technical skills acquisition.[8, 245, 272, 305] While some curricula teach CC's and their role is already well-recognized in plastic surgery, the research on defining them is limited.[5, 18, 70, 88, 95, 270] The methods suggested for their teaching are non-specific, such as peri-operative briefing and debriefing, simulation, mortality and morbidity meetings, and residents-run clinics.[88]

Acquisition of cognitive competencies in breast augmentation

This study recruited 15 residents in a self-controlled trial to compare the standard methods of education (control) to a CTA-based curriculum in PBA (intervention). To demonstrate this, knowledge was assessed through MCQs and cognitive competencies were assessed using three scales, two of which have been previously validated and used.[243, 312, 317, 321] The participants recruited were representative of various experience levels and exposure to PBA, with relative confidence levels and comfort in the procedure. Residents from two programs were recruited (10 juniors and 5 seniors), and experts were sampled from both programs and the community to allow for the representation of local standards. Multiple teaching methods are available for CC, CTA-based curricula have shown effectiveness in transferring CC in various contexts.[18, 244, 247, 282, 283] Additionally, the delivery of such curricula through web-based and virtual media has been demonstrated.[9, 18, 283] A CTA-based interactive curriculum was used to deliver CC in PBA and compared to traditional teaching where participants utilized books, journals and online resources.

Surgical knowledge of practical anatomy and pathology is the foundation for building CC, thus MCQs were used to assess baseline knowledge, which was higher for senior residents than juniors. The reason for their further improvement could be related to thought organization that optimizes knowledge application.[34] These scores improved for both groups before and after the intervention. A similar pattern was noted in the level of confidence in response to MCQs. The average interview duration was 36.6 minutes for the pre-test and 42.5 for the post-test. A total of 38 CTA-interviews were included in the analysis, 15 residents (pre and post) and 8 experts. Overall, all participants showed significant improvement in PSS, SDMRS, NOTSS (categorical score) following the intervention. When compared to experts, senior residents scored less, followed by junior residents. Despite being previously validated scores, the NOTSS scores were not consistently improved; specifically, communication and teamwork compared to improvement in other categories. This finding was similar for certain elements of the PSS, such as the issues in the recovery room. It can be argued that the curriculum was not effective at transferring these skills based on the experts' task-analysis. The improvement on other elements of these scores and the SDMRS was noted following the intervention, with scores nearing but not surpassing those of experts and seniors for their juniors. The focus of the learning modules on situational awareness and knowledge of important cues to base decisions on is evident on the representative sub-scores. These findings represent the ability to transfer most cognitive skills from expert task analysis to learners and the enhancement of the delivery system can optimize skills acquisition and establish long-term retention.

Assessment of cognitive competencies in breast augmentation – The role of CTA

Unlike observed technical skills, assessment of cognitive skills is more complex as they are deeper, tacit and are difficult to express by learners and measure by assessors.[8, 34, 311, 312] The difficulty mainly arises from the need for buy-in from both the assessors and learners.[311] The interview process in this study was standardized with semi-structured interviews and assessors were blinded to limit bias and increase the objectivity of assessment. The learners should be likewise engaged in the process, and the participating residents and experts alike perceived non-technical skills (cognitive and affective) to be important, albeit less important than technical ones. Multiple scoring systems in surgery were developed for non-technical skills with various focuses on elements surrounding a similar taxonomy of situation awareness, decision-making, task management, leadership and communication and teamwork.[242, 243, 311, 312] The choice of the scale depends on many factors and the importance is the reliability and validity of the assessment to allow for standardization. As CTA-based assessment is employed, NOTSS was included as an overall assessment of CC, SDMRS as a situation-specific assessment, and designed a PSS to correlate generic scores to the designed curriculum. This allowed for demonstration of the ability to measure differences in cognitive skills among various levels, relative to experts as well as to measure change following an intervention.

Establishing validity is important and can be achieved through different domains, including content, construct (relationship), reliability, response and clinical interpretability; the latter being more difficult to measure with low exposure rates.[11, 37, 301] The content of this curriculum was CTA-based on interviews of experts in the field, and likewise, the assessment tool created (PSS) was based on that data. The face validity was also checked by asking experts to define the important elements of the procedure through a previously carried out Delphi-based task analysis and modified based on feedback.[11] Construct validity can be demonstrated through the relationship between variables, with the ability of the PSS and other scores used to discriminate between juniors, seniors, and experts and correlate with the level of experience (PGY years). This was also noted between the cognitive scores (PSS, SDMRS, and NOTSS) with a significantly high correlation). The use of the experts-based CTA-curriculum as a criterion allows for criterion validity for the use of the same standard interview for assessing learners. Another criterion can be based on knowledge, which was demonstrated by the ability of MCQs to discriminate between different levels of experience (low correlation) and correlate well with the used cognitive scores. PSS was reliable with high internal consistency (Cronbach's alpha = 0.979) and moderate-high interclass-correlation (ICC) (Pearson correlation = 0.574 and 0.977 for each rater and average) representing inter-rater reliability.

While the medium of assessment varies in terms of the style of interview used, many CTA-based studies employed a talk-out-loud method, intra-operative observations, or knowledge scores to demonstrate skills acquisition.[8, 18, 242, 245, 247, 272, 282, 305, 322] The use of CTA can be equivalently used to elicit knowledge and subconscious decision-making processes that experts tend to leave out while teaching, let alone mid-level learners.[8, 248, 323, 324] Most board certifications require variants of a standardized oral exam that is dependent on the articulation skills of the examinee to demonstrate safe and effective decision-making.[325, 326] Future research will help define the role of CTA-integration in summative assessment exams within competency-based surgical education.

From theory to practice

Distinctive cognitive competency domains have been established along with core competencies common to various surgical specialties.[52, 242, 243] Despite cognitive skills assessment's availability in other domains of surgery, limited evidence exists in plastic surgery, and what exists is limited to assessments of basic skills (i.e. cognitive skill assessment of core procedures are lacking in plastic surgery).[5, 8, 9, 18, 86, 247, 249, 306, 312] The application of CTA-based competency training has demonstrated similar results in terms of skill acquisition.[18, 317] Additionally, the rapid development and change of simulation in plastic surgery education require a parallel understanding of essential competencies, including the cognitive domain.[1, 11, 327] A practical example is a work done on breast augmentation through establishing needs, producing a task-list, developing a technical skills simulators, and integrating it with a cognitive curriculum, which has been shown to improve technical skill acquisition in other contexts.[11, 281, 328] Additionally, CTA methods can be integrated into the process of an oral examination to aid learner and improve the exam standardization, but requires extensive training and development, and thus is subject to further research.[272] Future research can also study the effect of CC training on self-confidence (meta-cognition), establish further psychometrics, clinical performance, complications and patient satisfaction.[35] Lastly, given the role of non-verbal cues and emotions in decision-making, their integration into CC assessment can also be examined.[329-331] The limitations of the study include those inherent to CTA methodology, a relatively smaller sample size, and a lack of randomization and clinical interpretability.

10.5 Conclusions

The shift to competency-based surgical education and lack of educational and assessment tools that establish competency in plastic surgery calls for validity evidence on the effectiveness of CMBE. Further introduction and development of CC models into core procedures in plastic surgery to allow educators to integrate them into residency is required. In this study, we demonstrate the ability to define, teach, and assess CC in breast augmentation as an example.

11. Assessment of Marking and Perception Competency in Breast Augmentation

Becher Al-halabi[1,2], Melina Vassiliou[2], Mirko Gilardino[1]

1. Division of Plastic and Reconstructive Surgery, McGill University Health Centre, Montreal, QC, Canada.
2. Department of Surgery, McGill University Health Centre, Montreal, Quebec, Canada

11.1 Introduction

The variable exposure and lack of objective competency assessment in post-graduate medical training have created the need for competency-based models.[1-3, 12] Aesthetic surgery is an excellent example of a field where the elective nature of involved procedures limit residents' exposure.[1, 11, 15, 16] Competency-based training research has been focused on technical skills, but limited with regards to cognitive skills, including surgical planning and marking.[1, 3, 5, 17-19, 332]

Breast augmentation is commonly performed by plastic surgeons where decision-making has a direct effect on clinical outcomes and is the root cause for most litigations.[11, 229, 233-239] The use of pre-operative markings in breast surgery is an essential step that guides the procedure.[332-334] Using Cognitive Task Analysis (CTA), the process of expert decision-making and involved cognitive competencies (CC) can be identified.[8, 9, 247] Among previously studied cognitive tasks involved in Breast augmentation, marking was essential for the execution of surgical planning and is a reference point during the procedure. Testing of this important component of plastic surgery is limited despite its significance in surgical planning and teaching.[63, 332, 333, 335]

This self-controlled trial employs a CTA-based curriculum to study the effect of CC education on marking, perception and planning in Breast Augmentation. By demonstrating these skills among other CC, similar models can similarly be applied to other procedures. This serves as a primer to integrate their education and assessment in establishing resident's competency.

11.2 Methods

Instructional design

A systematic and theory-driven approach was used to identify CC in breast augmentation through CTA.[8, 248-250] Semi-structured interviews were designed to elicit experts' cognitive processing and were audio-recorded, transcribed and analyzed to synthesize 208 cognitive items and 41 complications used for curriculum design. Of these items over 85 (40.87%) were related to situation awareness and 15 (7.20%) were related to marking (Table 11.1). These competencies were used to design a curriculum composed of five modules on an interactive web-based multi-media enriched platform (Figure 10.1). The modules targeted pre-operative preparation, surgical judgement, implant selection, safety and complications, and surgical perception. Within the modules, several interactive exercises in pre-operative marking, plane and aesthetic principles perception, pre-operative planning and decision-making were integrated. The modules were piloted on a few medical students (n=5) and plastic surgeons (n=2) and reviewed for content, ease of use, clarity of graphics and multi-media and technical issues before use.

Participant selection and knowledge transfer

A systematic approach was employed to test CC involved in breast augmentation by performing CTA on participants regarding breast augmentation and on marking a presented case (Figure 11.1). Plastic surgery residents from different levels of two programs were invited to participate in this study. The invitation discussed the aims of the study and focus on cognitive skills, marking and perception and consenting participants were surveyed on self-perception and the importance of these skills relative to others. All participants were asked to prepare for two weeks using their usual study materials for a board-exam-style assessment on primary breast augmentation including markings (PBA) after which they underwent a pre-test followed by exposure to the CTA-based learning modules for two weeks (the intervention) and a post-test thereafter. Participants reported studying between 6-12 hours in the 1st stage of the trial, compared to 5 hours required to complete the CTA-based curriculum where they were asked to avoid exposure to any other resources or seeking answers to the interviews to avoid contamination.

Participant assessment

Semi-structured scenario-based response-guided interviews were used to assess CCs were through 20 standardized cognitive probes to elicit discussion. In addition, participants were asked to perform pre-operative markings of a young patient with otherwise normal anatomy for primary breast augmentation while running a commentary (Figure 11.2). CTA was also used to further elicit responses and question decision-making during the marking. Participants were encouraged to ask for cues and freely discuss their decisions, and cues leading to decisions. Interviewers received training on CTA and minimized close-ended questions, interruptions, or leading participants to avoid results contamination. The interviews were audio-recorded, transcribed verbatim, anonymized and scored by two different blind assessors using the Surgical Decision-Making Rating Scale (SDMRS) for the cognitive probes and the markings through de-novo created marking and surgical planning scale (MSPS). The marking exercise recordings were similarly processed and scored on four main components, breast anatomy, implant, incision, and pocket planning using.

SDMRS is a scenario-based surgical judgement rating scale developed in Canada that tests anatomic recognition, current task management, immediate surgical planning, avoidance of complications, and higher-level planning.[317, 318] The scale uses a different linear ascending score of 1-5 (highest) for each element with a composite score of 25. Results from CTA on experts were used to design the MSPS with four main components, breast anatomy, implant, incision, and pocket planning with a score of 5 per component and a maximum composite score of 20 (Table 11.2). The rating-scale used specifically for this CTA-based assessment focused on the items mentioned (recall and awareness), the ability to explain reasoning (decision-making), and the need for prompting by the interviewer. In addition, marking related factors were collected using a web-based marking application specifically designed for this study. Data collected included the output of the during that was anonymized to guide the assessment, total interview time, stroke time, number of moves (reflecting fluidity), and confidence in each component of the marking.

11.3 Results

A total of 18 residents were recruited to the study, out of which 15, 10 Junior (PGY 1-3) and 5 Senior (PGY 4-5), completed all components of the study (Table 11.3). Residents reported low confidence/comfort in performing PBA with low exposure rates in terms of procedures prior to the exposure. Participants perceived all skill domains equivalently important with less importance put on cognitive and affective skills. Senior residents, in general, displayed higher confidence and comfort level with higher exposure to the procedure.

A total of 38 CTA-interviews were included in the analysis, 15 residents (pre and post) and 8 experts. Overall, all participants showed significant improvement in SDMRS following the intervention (Table 11.4, Figure 11.4). Scores for seniors and juniors improved following the intervention but didn't reach experts' scores. This was true for all subset scores as well with significant improvement in complications avoidance and higher-level planning. The final scores were higher for experts (24.2/25), relative to 17.4 and 15.9 for junior and senior post-test scores, respectively.

Marking interviews were longer for senior residents relative to juniors, with an increase in duration post-intervention (Table 11.4, Figure 10.5). In terms of marking assessment, whereas juniors had reduced marking time and moves following exposure to the intervention, seniors displayed longer marking times, with more moves compared to experts that were recognized by short marking time with fewer moves. Overall, the MSPS scores improved for both subgroups following exposure but did not reach expert levels, with one exception. Breast anatomy scores for senior residents remained stable, while those for junior residents improved significantly reaching, or even greater than, the scores of the seniors. Lastly, both subsets of residents felt more confident following the intervention in all aspects of PBA marking including anatomy and planning.

Table 11.5 shows the correlation between different assessment scores and level of experience (PGY years). The correlation between MSPS and SDMRS and subcomponents and was significantly high, as well as with experience level and marking confidence. Specifically, the MSPS best correlated with the current task management and immediate surgical planning subsets of the SDMRS. When examining the MSPS for reliability, the Cronbach's alpha was 0.938 between domains and 0.939 across all scores. Interclass-correlation (ICC) moderate for each rater (0.790) and high for both raters (0.938).

11.4 Discussion

The limited focus on the "Cognitive" domain of surgical education requires improving ways of skills acquisition and assessment given the complexity of this skillset.[34, 249, 269, 274] The literature suggests the importance of decision-making and other CCs in implant selection, injury prevention and risk communication.[292-294, 299] Cognitive skills can also vary depending on the context of the procedure, and thus curricula should establish essential competencies prior to skill transfer.[243, 244, 249, 274, 289] Five main domains classify cognitive competencies, situation awareness, decision-making, task management, leadership and communication and teamwork.[242, 243] Reasoning lies on a cognitive-load spectrum, by which alertness to a task can vary from subconscious to a maximal cognitive demand depending on the level of experience, the performer's comfort and complexity of the task.[274, 289, 300] This process involves gathering variables, establishing a plan and executing it.[88] In this study, the focus is on two elements of this process, namely perception as a means of situational-awareness (gathering) and marking as a sign of demonstrating a plan (decision-making) through a self-controlled trial.

The importance of surgical perception in decision-making

Perception is an element of cognitive competencies (CC) that involves gathering internal and external cues that are essential for appropriate decision-making. These can include visuospatial cues, meta-cognition, and pattern recognition of tissue properties, such as colour, texture and relationships.[243, 282, 283, 336, 337] This skill falls under the domain of situational awareness, one of the most essential competency domains that affect decision-making and consequently outcomes.[243] Evidence suggests that perception is a skill that can be transferred and learnt over residency, but despite its theoretical simplicity, essential concepts such as plane recognition are difficult to transfer in a timely manner to residents. This creates a risk for complications during the learning phases and steepens the learning curve.[336, 338] Mostly, this difficulty arises from the automatization of experts' pattern recognition that allows them to point the right plane to learners, creating a gap in teaching.[274, 289, 300] Perception proves further importance in plastic surgery where the recognition of anatomical variations and pathological anatomy is important, but also the three-dimensional appreciation of volumes, proportions, and aesthetics.[335, 339] Three-dimensional perception varies across levels of experience and requires ample exposure; research suggests improved performance after training with a three-dimensional model relative to a two-dimensional one.[340] Situation awareness is gathering cues (external/internal) to anticipate future states and thus allow for improved surgical safety through forward planning, prospective hemostasis and plane-recognition.[243] Such awareness constitutes the fundamental for surgeons' reasoning, deliberation and slowing-down in critical scenarios and moves a novice down a cognitive-load continuum into implicit and sub-conscious proficiency and accelerates technical skill.[8, 88, 245, 269, 272, 300, 305]

Previous CTAs of different procedures in surgery including work by the authors identify the importance of knowledge of cues and their perception on safety and decision-making.[242, 243, 272, 273, 320] A CTA-based interactive curriculum was used to deliver CC in PBA with a focus on perceptive and marking skills through a series of interactive exercises based on defined competencies. This was compared to traditional delivery where participants utilized books, journals and online resources and used an average of 8.2 hours. Results suggest that CC education improves perception and decision by examining subsets of two main scores, the SDMRS and the MSPS. Anatomical awareness was improved following the intervention evident by improvement in the Anatomic Recognition domain of the SDMRS and the Breast Anatomy marking component of the MSPS. Moreover, residents planning scores improved following the intervention evident by immediate surgical planning component of the SDMRS and improved planning scores for the implant, incision and pocket under the MSPS through a talk aloud assessment. Lastly, safety was an important component of the MSPS which showed an improvement in total scores following the intervention and correlated to an increase in the SDMRS avoidance of complications scores. The focus of the learning modules on situational awareness, knowledge of important cues to base decisions on is evident on the representative sub-scores.

Marking as a surrogate of cognitive competencies in breast augmentation

The importance of marking in surgical specialties extend beyond surgical site errors, approach and exposure.[341-344] In fact, markings assist surgeons intra-operatively, prevent complications, optimize clinical outcomes and aid in teaching.[63, 141, 343, 344] Conversely, inappropriate markings and lack of plane perception lead to inaccurate ablation risking pathological recurrence, wrong surgical site occurrence, or even misguide a surgeon into false anatomical spaces and risk complications.[244, 342, 345, 346]

Data from CTA of breast augmentation demonstrated that marking required appropriate understanding of surgical anatomy, perception of patient-specific anatomy and ideal aesthetics, and lastly personal professional judgement and pattern-recognition that allows for decision-making. A CTA-based curriculum was used as an intervention and compared to the standards of teaching as a control to study the effect of improved CCs on the residents' ability to mark a standardized patient for PBA. Data from this study suggest an improvement in all aspects of the MSPS used to reflect on the ability to safely mark a plan on a patient with respect to their surgical anatomy and planning of their incision, implant, and pocket. The residents' confidence in marking improved as well. Senior residents were found to have no improvement in their marking of breast anatomy, which could be related to their disregard for this part of teaching or forward planning and focus on other components of planning.

By combining the output of residents and their CTA-style talk aloud allowed for a representative understanding of their ability to mark a patient based on a CTA-generated marking scale relative to experts. The MSPS also correlated to previously established scales for decision-making (SDMS) with significantly high correlations to all sub-components. The scale was also higher for seniors than junior residents for most sub-domains and overall pre and post-intervention and correlated with the level of experience. Lastly, the MSPS was reliable with high internal consistency (Cronbach's alpha = 0.938) and interclass-correlation (ICC) (Pearson correlation = 0.790 and 0.938 for each rater and average) representing inter-rater reliability. These findings display the effect of cognitive skills learning on pre-operative marking following a CTA-based curriculum exposure. The data also suggests that marking can be used as a surrogate to surgical planning and decision-making and thus its teaching and assessment are essential in competency assessment of CC.

Many tools have been developed in plastic surgery to aid in surgical planning, from as simple as marking the edge of a dermatome to ease graft harvest[110], using slide shows to teach markings[63, 141, 154], to the end of developing simulators that incorporate marking.[74, 333, 335, 347, 348] In a 2008 report, residents asked to mark a carpal tunnel release had critical issues in marking that the authors attributed to deficiencies of surface anatomy understanding, exaggerating incisions and indecisiveness.[332] Qualitative analysis of the markings done by junior and senior residents pre/post the intervention revealed similar findings, and this possibly explains the correlation between markings and decision-making, including the understanding of the patient's anatomy. Moreover, it was difficult to interpret system-based acquired data such as marking strokes (moves) and the marking time, but further development of the system can improve the ability to detect decisiveness. The teaching and assessment of marking, an extremely crucial part of plastic surgery, is underscored in competency assessment, despite its increased application in board exams.[63, 154, 326, 332, 335] Despite the correlation of the ability to mark with decision-making and planning, further research and automatization of the assessment can be used to establish competency and provide feedback. Recent research on visual concordance can become applicable in automatizing the process of marking assessment.[282, 283]

From theory to practice

Marking and perception are elements of competencies common to various surgical specialties but are of special importance in plastic surgery.[52, 60, 74, 242, 243, 335, 338] Cognitive skills assessments are available in surgery and plastic surgery nonetheless, such as flexor tendon repair and burns, but is constrained within basic skills and lack competency assessment of core procedures.[5, 8, 9, 18, 86, 247, 249, 306, 312] The application of CTA-based competency training has demonstrated similar results in terms of cognitive skills acquisition[18, 317], but this study focused on the role of marking and perception and their correlation to CC training. Work on breast augmentation where a technical skills simulator has been developed can allow for integrating a cognitive curriculum with a focus on safety, plane perception and marking.[11, 281, 328] Additionally, automatized marking assessment and feedback can be integrated into the process of an oral examination to aid learners and standardize the exam.[272] Data from this study suggests improvement of self-reported confidence and the analysis of non-verbal cues and emotions and their correlation with decision-making can provide further insight into experts behaviour.[329-331] The limitations of the study include those related to CTA methodology and the designed curriculum, limitations of the developed web-based tool in terms of two-dimensional display, and restricted expression of novices.

11.5 Conclusion

The shift to competency-based surgical education and lack of educational and assessment tools that establish competency in plastic surgery calls for validity evidence on the effectiveness of CMBE. Further introduction and development of CC models into core procedures in plastic surgery to allow educators to integrate them into residency is required. In this study, we attempt to introduce and demonstrate the ability to teach and measure marking and perception as an essential competency in surgical planning.

12. Comprehensive Discussion of Findings

This project aimed to develop an understanding of cognitive competencies involved in plastic surgery and pave the path for teaching and assessing cognitive competencies in aesthetic and plastic surgery.

A systematic approach should be used when designing tools that demonstrate competence. Appraising available models for competency assessment and areas of need allowed for better planning of transition to practice in plastic surgery. An understanding of instructional design requires proper analysis and planning, evidence-based design, and validated assessment. A systematic search of multiple databases assessing for design, quality, competency assessment, and objective alignments to ACGME competencies and RCSPC CanMEDs roles was performed. Overall, a scarcity of interventions was noted targeting a mix of learning domains with weak learning evaluation and evidence of validity; the average MERSQI score was 10.9/18. The plastic surgery educational literature was of average quality and was limited in the involvement of competency assessment. This calls for improvement in conducted educational research in this field and involving all learning domains and alignment of objectives to all competencies in prospectively developed interventions.

A notable example of established practices in plastic surgery education is resident-run clinics (RRCs) that provide semi-independent environments through progressive autonomy and centralize the care around patient satisfaction. This provides society-catered safe learning that addresses all ACGME competencies and the roles of the Royal College of Physicians and Surgeons of Canada (RCSPC). This is especially important for building residents' professionalism and accountability by taking responsibility for outcomes that traditional teaching models of aesthetic surgery lack. RRCs develop cognitive competencies through a controlled and supervised trial and error process by allowing autonomous learning and decision-making thus boosting confidence and system-based learning. Within CBME, the ability to measure the progress and competency makes RRCs an optimal environment to attain the six ACGME core competencies but has its limitations in terms of issues in the establishment, maintenance and applicability that were previously described.

The choice of breast augmentation as a model procedure for this work is its identification as an index aesthetic procedure (EPA) that covers many of the competencies needed to perform other aesthetic procedures. However, despite its common practice, the exposure to this procedure is lacking and graduates lack confidence in performing it. Canadian programs are especially affected with lower confidence in Breast augmentation. Besides, the high indictment rates of breast augmentation leading to the award of damage or settlements highlight the issues of improper pre-operative planning, communication and patient selection rather than technical errors. Thus, addressing the cognitive aspect of this procedure becomes as important, if not more important than the technical aspect.

The benefit of cognitive competency education in fast-tracking technical skills training as they reduce the learner's cognitive load also allows error recognition and prevention. However, awareness of such skills is limited to most educators' perceptions and this holds in plastic surgery. Cognitive task analysis (CTA) was used to define a framework of competencies to allow for the development of a technology-enhanced learning tool to teach cognitive competencies and allow learners to deliberately practise decision-making.

Although this is a new approach to education in aesthetic plastic surgery, it has been previously demonstrated in reconstructive surgery (tendon repair) and various other procedures in general surgery and intensive care. To develop valid educational and assessment tools an in-depth analysis of the reasoning process used in different types of plastic surgery allows educators to target different competencies geared to the procedure. Thus, cognitive competency domains are common to procedures, but procedure-specific competencies vary depending on the focus and objectives of the procedure.

Cognitive Competencies are a set of perceptive and interpersonal skills used in surgical care within one of situation awareness, decision-making, task management, leadership and communication and teamwork. Situation awareness allows gathering cues (external/internal) to anticipate future states, while decision-making explores options given the cues and communicating, implementing and reviewing (prospectively/retrospectively) such decisions. Task management is to plan and flex around changes, while leadership is setting standards to others, supporting them and coping with a pressured environment. Lastly, communication and teamwork involve information exchange to construct a plan.

This study recruited 15 residents in a self-controlled trial to compare the standard methods of education (control) to a CTA-based curriculum in breast augmentation (intervention). All participants showed significant improvement in knowledge, PSS, SDMRS, NOTSS following the intervention. The focus of the learning modules on situational awareness and knowledge of important cues to base decisions on was evident on the representative sub-scores. These findings represented the ability to transfer cognitive skills from expert task analysis to learners. The content of this curriculum was CTA-based on interviews of experts in the field and was reviewed by other experts. The relationship between the variables examined demonstrated the ability to discriminate between juniors, seniors, and experts and correlate with the level of experience. The correlation, reliability and validity of the assessment demonstrated the ability to use CTA-based assessment to measure CTA-defined cognitive competencies in breast augmentation.

This work also examined perception as a means of situational-awareness (gathering) and marking as a surrogate for planning (decision-making) through a self-controlled trial. Perception involves gathering cues and is a skill that can be transferred and learnt over residency. Its role in plastic surgery is fundamental for surgeons' reasoning. Results suggest that CC education improves perception and decision by examining subsets of two main scores, the SDMRS and the marking and surgical planning score (MSPS). CC education improved anatomical awareness and planning scores for the implant, incision and pocket. Marking, on the other hand, is integral to the function of plastic surgery, and inappropriate markings and lack of plane perception lead to false anatomical guidance and risk complications. Data from CTA of breast augmentation demonstrated that marking required appropriate understanding of anatomy and ideal aesthetics and pattern-recognition that allows for decision-making. This study suggests an improvement in all aspects of the MSPS used to reflect on the ability to safely mark surgical anatomy and the plan of their incision, implant, and pocket. The MSPS correlated with previously established scales for decision-making (SDMS) and discriminated among levels of experience with high reliability. These findings display the effect of cognitive skills learning on pre-operative marking following a CTA-based curriculum exposure and the importance of marking in assessing surgical planning and decision-making.

The rapid development and change of simulation in plastic surgery education require a parallel understanding of essential competencies through establishing needs, producing a task-list, developing a technical skills simulator, and integrating it with a cognitive curriculum, which has been shown to improve technical skill acquisition in other contexts. CTA methods can be integrated into the process of competency examination to aid learner and improve the exam standardization, but requires extensive training and development, and thus is subject to further research. Future research can also study the effect of CC training on self-confidence (meta-cognition) given the role of non-verbal cues and emotions on decision-making to integrate them into CC assessment. Marking and perception competencies can also be assessed through the application of CTA-based and the development of automatized marking assessment and feedback to aid learners.

13. Conclusions and Summary

A systematic review of the plastic surgery literature assessed the quality of educational interventions to guide the creation of tools that assure competency among trainees. Overall, the reviewed literature was of average quality, with limited involvement of competency assessment requiring improvement in conducted educational research in this field, and an increased focus on teaching and assessing of the cognitive domain. RRCs in aesthetic surgery are an example of competency assessment in training but there remains a gap between the perception of faculty and residents with regard to aesthetic training. The merit of RRCs in terms of being an autonomous learning platform is optimal competency-based learning within aesthetic surgery training. Using a qualitative methodology, a framework for the various cognitive processes required to perform breast augmentation along with possible pitfalls that can arise with such a procedure was established. The data from this study was used to develop interventions aimed to teach and assess these competencies to enhance surgical training, improve performance and avoid pitfalls. But to introduce cognitive competencies into plastic surgery, a comparison between different procedures is important to understand the various methods used in reasoning. Thus, two models of distinct procedures in plastic surgery and provide educators with a priming framework for teaching and assessing such competencies in plastic surgery. The practicality and effectiveness of teaching such competencies are theoretically established but are yet to be demonstrated. This requires further introduction and development of CC models into core procedures in plastic surgery to allow educators to integrate them into residency training. To demonstrate the ability to define, teach, and assess CC in breast augmentation as an example, a self-controlled trial was designed using a CTA-based curriculum. Results demonstrated the ability to transfer and measure cognitive competencies in plastic surgery. To introduce and demonstrate the ability to teach and measure marking and perception as an essential competency in surgical planning, the effect of this curriculum was established as well. Overall, this work demonstrates the lack of developed educational research in competency assessment of the cognitive domain to which RRCs were found optimal to address. Despite this, the understanding, defining and assessment of these competencies are essential and were demonstrated through the results of the presented data.

14. Tables, Figures and Appendices Legend

14.1 Tables

14.2 Figures

14.3 Appendices

Appendix 1. Summary of 35 items for subthemes within general considerations synthesized after 5 rounds of data analysis for the success of primary breast augmentation.
Appendix 2. Summary of 77 items for sub-sections within pre-operative planning synthesized after 5 rounds of data analysis for the success of breast augmentation.

Appendix 3. Summary of 32 items for sub-sections within peri-operative preparation synthesized after 5 rounds of data analysis for the success of breast augmentation.

Appendix 4. Summary of 28 items for sub-sections within pocket dissection and design, synthesized after 5 rounds of data analysis for the success of breast augmentation.

Appendix 5. Summary of 23 items for sub-sections within implant handling and insertion, synthesized after 5 rounds of data analysis for the safety of breast augmentation.

Appendix 6. Summary of 13 items for sub-sections of pocket and skin closure and postoperative care, synthesized after 5 rounds of data analysis for the success of breast augmentation.
Appendix 7. Summary of 2 issues with pre- and peri-operative care, synthesized after 5 rounds of data analysis. Root pitfalls, risks, preventative measures and management were identified.

Appendix 8. Summary of 3 issues with Intra-operative care, synthesized after 5 rounds of data analysis. Root pitfalls, risks, preventative measures and management were identified.

Appendix 9. Summary of 11 issues associated with implant insertion and handling, synthesized after the five rounds of inductive data analysis. For each issue, root pitfalls and causes, risks, preventative measures and management strategy were identified.

Appendix 10. Summary of 25 post-operative issues, synthesized after the five rounds of inductive data analysis. For each issue, root pitfalls and causes, risks, preventative measures and management strategy were identified.

15. Tables Figures and Appendices

15.1 Tables

Variable	Frequency (%)	Competency-based (%)
Included educational interventions	36 (100)	29 (80.6)
Study aim		
Descriptive	11 (30.6)	7 (63.6)
Evaluative	25 (69.4)	22 (88.0)
Type of educational intervention		
Teaching	18 (50.0)	13 (72.2)
Assessing	11 (30.6)	10 (90.9)
Mixed	7 (19.4)	6 (85.7)
Type of simulation		
None	4 (11.1)	3 (75.0)
Computer	7 (19.4)	5 (71.4)
Physical	20 (55.6)	17 (85.0)
In-situ	4 (11.1)	4 (100.0)
Smart Devices	1 (2.80)	0 (0.00)
Medium of simulation		
N/A	4 (11.1)	3 (75.0)
Software-based	4 (11.1)	4 (100.0)
Touch screen	1 (2.80)	0 (0.00)
Video-based	1 (2.80)	1 (100.0)
Web-based	2 (5.60)	0 (0.00)
Inanimate	10 (27.8)	9 (90.0)
Cadaveric - Humans	5 (13.9)	3 (60.0)
Cadaveric - Animal	3 (8.30)	3 (100.0)
Excised tissue - Humans	1 (2.80)	1 (100.0)
Live - Pig	1 (2.80)	1 (100.0)
Immersive clinical simulation	3 (8.30)	3 (100.0)
In-situ	1 (2.80)	1 (100.0)
Bloom's taxonomy of learning domains		
Psychomotor	6 (16.7)	6 (100.0)
Cognitive	6 (16.7)	2 (33.3)
Affective	1 (2.80)	1 (100.0)
Mixed	23 (63.9)	20 (87.0)

Table 2.1 Summary of the general characteristics extracted from 36 educational Interventions, stratified by the involvement of competency assessment.
N/A – Not applicable

Quality assessment	Frequency (%)
Included educational interventions	36 (100)
Level of competency/outcome assessment involvement	
None	7 (19.4)
Objective - Oriented to assess/improve graduate outcome	4 (11.1)
Design - Organized around analysis of societal/patients need	16 (44.4)
Implementation – Learner-centered (increased accountability)	9 (25.0)
Score on Validity Evidence Domain (4/4) – Mean (STD)	
Content	3.03 (1.06)
Response Process	3.22 (1.02)
Internal Structure	1.92 (1.05)
Relation to Other Variable	1.44 (0.94)
Consequences	2.03 (0.91)
Kirkpatrick's Learning Evaluation Model	
Reaction – How participants react to the learning intervention	8 (22.2)
Learning – Demonstration of learning in participants	10 (27.8)
Behaviour – In situ change of participants' behaviour	15 (41.7)
Results – Change in outcomes	3 (8.30)
Overall – Mean (STD)	2.36 (0.93)
MERSQI (18/18)	
1-5	4 (11.1)
5-9	8 (22.2)
10-14	19 (52.8)
15-18	5 (13.9)
Overall – Mean (STD)	10.9 (3.87)
Study Design – Mean (STD)	1.50 (0.57)
Randomized Controlled Trials – N (%)	2 (5.60)
Sampled institutions and response rates – Mean (STD)	1.72 (0.45)
Type of data gathered – Mean (STD)	2.33 (0.96)
The validity of Evaluation Instrument – Mean (STD)	1.58 (0.97)
Data analysis – Mean (STD)	1.94 (1.41)
Outcome– Mean (STD)	1.82 (0.62)

Table 2.2 Summary of the quality assessment of the included 36 educational Interventions
STD – Standard Deviation;
MERSQI - Medical Education Research Study Quality Instrument

Involved Field	Frequency (%)	MERSQI Mean (STD)	Kirkpatrick* Mean (STD)	Competency Based** (%)
All Fields	36 (100)	10.9 (3.87)	2.36 (0.93)	29 (80.6)
Aesthetic Surgery	4 (11.1)	11.4 (3.90)	2.50 (1.29)	12 (10.3)
Burn Surgery	1 (2.80)	11.0 (0.00)	1.00 (0.00)	1 (3.40)
Craniofacial Surgery	2 (5.60)	11.5 (4.95)	3.00 (0.00)	2 (6.90)
Pediatric Surgery	2 (5.60)	10.0 (4.95)	3.00 (0.00)	3 (6.90)
Hand Surgery	5 (13.9)	13.0 (0.61)	2.40 (0.55)	8 (17.2)
Oculoplastic Surgery	1 (2.80)	4.00 (0.00)	1.00 (0.00)	1 (3.40)
Reconstructive Surgery	15 (41.7)	10.1 (4.35)	2.20 (0.94)	12 (37.9)
Ethics and Professionalism	2 (5.60)	13.8 (1.06)	3.50 (0.71)	2 (6.90)
Education and Assessment	4 (11.1)	11.25 (4.50)	2.25 (0.96)	4 (6.90)

Table 2.3 Quality of educational interventions stratified by relevant field of Plastic Surgery
* Kirkpatrick's Learning Evaluation Model
** Column percentages are reported
STD – Standard Deviation;
MERSQI - Medical Education Research Study Quality Instrument

Factor	Traditional Training	Resident-Run Clinics
Model	Didactic teaching, designated rotations	Competency-based, surgical autonomy
Goal	Knowledge acquisition	Knowledge application
Technical Skills	Limited Exposure	Improved Exposure as Primary Surgeon
Business Model	Personalized and private cosmetic services	Affordable cosmetic surgery
Autonomy	Static, Staff dependent	Progressive, resident dependent
Continuity of Care	Low pre- and post-operative resident involvement	High pre-operative decision-making and post-operative follow-up
Accountability	Attending surgeon	Chief resident and Supervising Attending
Revenue	Pay-for-Service	Not-for-Profit Function
Assessment	Content-based	Standardized objective milestones, through progressive autonomy

Table 4.1 Comparison of Traditional Aesthetic Training and Resident Run Aesthetic Clinics in Terms of Function and Outcomes

Number	**Cognitive Probe**
1	24 years old female – Case of hypo-mastia with normal anatomy
1.1	Pre-operative marking of the patient in probe 1
2	25 years old female – Case of Bilateral Tuberous breast
3	19 years old female – Case of unrealistic expectations in size and incision
4	Day of surgery issues
5	Incision location and creation (Focusing on inframammary approach)
6	Sub-glandular plane – knowledge, opinion, and factors affecting the decision
7	Inadvertent over-dissection through a sub-glandular plane
8	Sub-pectoral plane – knowledge, opinion, and factors affecting the decision
9	Pocket creation – essentials and sequence of dissection
10	Pocket creation – inadvertent over dissection of pocket in a sub-pectoral plane
11	Deep dissection into serratus or Pectoralis Minor
12	Concept of prospective hemostasis
13	Uncontrollable bleeding intra-operatively – management and prevention
14	Dual plane – indications, types and decisions
15	Implant preparation, handling and insertion
16	Final adjustments – globular looking breasts – pocket too tight
17	Final adjustments – asymmetry on either side
18	Pitfalls of dissection – symmastia and capsular contracture
19	Skin closure and associated issues
20	Implant loss and failure

Table 6.1 Cognitive probes identified during the design phase used to run cognitive task analysis interviews.

Interview characteristics	Result
Age of SMEs –	
Median (IQR)	39.0 (26)
Range (minimum-maximum)	35 – 66
SMEs years of experience	
Median (IQR)	7.00 (23)
Range (minimum-maximum)	4 - 33
SMEs gender – n (%)	
Male	7 (87.5)
Female	1 (12.5)
SMEs number of performed breast augmentations – n (%)	
50-100	4 (50.0)
>250	4 (50.0)
SMEs number of days involved in residents teaching – n (%)	
Once / Week	2 (25.0)
2-3 times / Week	1 (12.5)
3-5 times / Week	5 (62.5)
SMEs setting of performing most aesthetic cases	
Private practice	7 (87.5)
Hospital-based practice	1 (12.5)
Interview duration (minutes)	
Median (IQR)	42.0 (15)
Range (minimum-maximum)	24 – 67

Table 6.2 Summary of 8 cognitive task analysis interviews performed on six SMEs.
SME – Subject matter expert;
IQR – Interquartile Range

Section of the Procedure	**Total Items**	**Situation Awareness n (%)**	**Decision-Making n (%)**	**Item Distribution**
Overall	208	85 (40.87)	123 (59.13)	
General Concepts:	35	15 (42.86)	20 (57.14)	
Anatomical Considerations	9	6	3	
Elements of Success	7	2	5	
Principles of Dissection	9	2	7	
Prospective Hemostasis	4	2	2	
Indications and Limitations	6	3	3	
Pre-operative Planning:	77	37 (48.05)	40 (51.95)	
Pertinent History	4	4	0	
Physical Examination	9	7	2	
Exploring and Addressing Patient Expectations	8	3	5	
Joint Decision Making	43	17	26	
Surgical Plan and Informed Consent	13	6	7	
Peri-operative Preparation	32	11 (34.38)	21 (65.63)	
Perioperative Preparation and Marking	19	8	11	
Draping and Positioning	9	2	7	
IMF Incision and Dissection to Deep Fascia	4	1	3	
Pocket Dissection and Design	28	14 (50.0)	14 (50.0)	
Subglandular Pocket Dissection	5	4	1	
Subpectoral Pocket Dissection	14	8	6	
Managing Intraoperative Errors	9	2	7	
Implant Handling and Insertion	23	4 (17.39)	19 (82.61)	
Pocket Preparation	4	1	3	
Implant Preparation and Handling	6	0	6	
Implant Insertion and Pocket Adjustments	13	3	10	
Pocket and Skin Closure and Postoperative Care	13	4 (30.77)	9 (69.23)	
Pexying of Fascia and Closure of Skin	9	4	5	
Dressing and Post-operative Plan	4	0	4	

Table 6.3 Items identified and synthesized after five rounds of data analysis for each general operative theme and procedural task for breast augmentation based on eight expert interviews.
Red – Situation Awareness;
Blue – Decision-Making

	Interviews	SMEs	Observations	Published Literature
Breast augmentation	**8**	**5**	**19**	**21**
Flexor tendon repair	**3**	**3**	**0**	**0**
Total	**11**	**8**	**19**	**21**

Table 8.1 Sources of qualitative data derive from literary sources, cognitive task analysis of subject matter experts (SMEs), and observations by type of procedure.

Competency	Teaching	Assessing	Media and Examples
Situation awareness	Surgeon-learner interactions through the critique of observations and assumptions	Knowledgebase, evaluation of self and environment and detecting risks, errors and complications	VP/ VR, MCQs Art course to improve judgment of proportions (Thompson-1972) Self-appraisal through M&Ms presentation
DM- clinical reasoning (Rule-based)	Express reasoning and critique and display of premises leading to expert reasoning	Exploration of: - Questions posed to reach reasoning - Factors leading to reasoning - Role of the knowledgebase in eliciting decision - Justification for action - Visible outcome (response / action) - Characterization of judgement relative to experts	SCI, VP, MCQs The burns suite (Sadideen – 2014);
DM – Deliberation (Analytical)	Focus on technical variables leading to various pathways in decision and reasons for the expert decision		SCI / In situ / CBS Flexor tendon repair (Luker - 2008); Virtual surgery simulation (Oliker - 2012)
DM – Personal professional judgement	Personal narrative, from trainee and educator, and demonstration of the process leading to a given plan		SCI / In situ Professional Meetings, rounds External septorhinoplasty (Wright - 1981)
DM – Practical wisdom (Virtue)	Focus on non-technical variables leading to the expert decision in a given scenario		SCI / In situ / CBS Resident run clinics (Pu, Pyle – 2006, 2010)
DM – Professional judgement (Recognition)	Focus on the "big picture" and combining products of reasoning to reaching an ultimate decision		SCI / In situ / CBS Resident run clinics (Pu, Pyle – 2006, 2010); Intra-operative CT planning (Ibrahim – 2011)
Task Management	Trainee's proposal of an action plan with critique from the educator in an individualized patient context	Identification of overall goals of care, development of action and contingency plans	SCI / In situ / CBS Resident run clinics (Pu, Pyle – 2006, 2010); Template to mark flaps (Townend – 1993)
Leadership	Stress management, personal and environmental resource management	Demonstration of leadership in situ and in simulated environments	SCI / In situ / Organizing rounds 360° Evaluations (Pollock – 2008) Resident run clinics (Pu, Pyle – 2006, 2010)
Communication and Teamwork	Interpersonal and communication skills through communication with team and patients	Demonstration of skills in situ and in simulated environments	SP / SCI / In situ Observation Surgical timeout / Consent 360° Evaluations (Pollock – 2008); Combined curriculum (Hultman – 2013)

Table 8.2 Methods and media identified from the literature to teach and assess each domain of cognitive competencies.
DM: Decision Making; SCI: Simulated Clinical Immersion; SP: Simulated Patient; CBS: Computer-Based Simulation (VP: Virtual Patient; VR: Virtual Reality).

Procedure Specific Scale			
Rubric		**Elements**	
5	Mentions most important points without prompting; able to explain reasoning; enhances safety	- Preoperative	Expectations History Physical exam Measurements Consent
4	Mentions most points with or without prompting, satisfactory; explains reasoning but with some difficulty	- Decisions	Implant-fill Implant-shape Implant-texture Implant-size Implant-width Implant-projection
3	Mentions some points with or without prompting; limited reasoning	- Perioperative	Implants Marking Pre-operative timeout Position
2	Does not mention; or does not know with prompting, no reasoning	- Intraoperative	Incision planes Pocket planes Muscle release Pocket dissection Limits of dissection Pocket preparation Sizer testing Implant handling Closure
1	Does not mention, gives wrong information; potentially endangers patient	- Recovery Room - Post-Operative - Safety	Issues Care and Plan Error Prevention Error Recognition Error Mitigation Error Management

Table 10.1 Procedure Specific Score (PSS) – elements and assessment rubric – 7 domains, score (1-5), a maximum composite score of 35.

Participant characteristics	All	Junior Residents	Senior Residents	Experts
All	23 (100.0)	10 (43.5)	5 (21.7)	8 (34.8)
Age (Years) (P = <0.001)	35.7 (11.92)	28.7 (2.54)	30.2 (1.79) *	47.8 (13.4) ^
Male Gender – n (%) P = 0.862	20 (87.0)	9 (90.0)	4 (80.0)	7 (87.5)
Interview duration (Minutes) - μ (STD)	P = <0.001			43.6 (12.7)
Pre-test (P = <0.001)	36.6 (3.9)	32.7 (2.6)	38.9 (2.3)	P = 0.163
Post-test (P = 0.03)	42.5 (3.2)	40.9 (1.3)	46.5 (2.9)	P = 0.810
Self-Perception of PBA- (/10) μ (STD)				
Confidence (P = <0.001)	5.26 (3.86)	2.10 (1.52)	4.40 (3.13) ^	9.75 (0.71) ^
Comfort (P = <0.001)	5.35 (3.69)	1.90 (1.60)	5.40 (1.34) ^	9.63 (0.74) ^
Perception of importance - (/10) μ (STD)				
Psychomotor skills (P = 0.035)	8.96 (1.52)	8.20 (1.81)	8.80 (1.30) *	10.0 (0.00) ^
Cognitive skills (P = 0.032)	8.87 (1.21)	8.40 (1.27)	8.40 (1.14) *	9.75 (0.71) ^
Affective skills (P = 0.022)	8.52 (1.65)	8.00 (1.70)	7.60 (1.82) *	9.75 (0.46) ^
Past year experience with PBA (Performed P < 0.001 / Assisted P = 0.254) – (n %)				
None	11 / 7	9 / 5	2 / 2	0 / NA
1-5 Procedures	4 / 3	1 / 3	3 / 0	0 / NA
6-15 Procedures	4 / 4	0 / 2	4 / 2	4 / NA
> 26 Procedures	4 / 1	0 / 0	4 / 1	4 / NA

*Not statistically significant – Compared to Junior Residents
^ P Value <0.05 – Compared to Junior Residents
Table 10.2 Study participants with a comparison between senior and junior residents.
NOTSS (Non-Technical Skills for Surgeons); SDMRS (Surgical Decision-Making Rating Scale);
PBA (Primary Breast Augmentation)

Interview Scores - μ (STD)	Junior Residents		Senior Residents		Experts
	Pre-Test	Post-Test	Pre-Test%	Post-Test	
All – n (%)	10 (43.5)		5 (21.7)		8 (34.8)
Knowledge - MCQ Score (/20)	11.8 (2.55)	16.5 (2.68) ^	13.6 (2.72) *	18.6 (1.58) *	-
Procedure Specific Score (/35)	20.8 (2.07)	24.4 (2.41) ^	21.8 (3.03) *	27.2 (3.40) ^	33.9 (0.33) ^
Preoperative Planning	3.04 (0.34)	3.65 (0.36) ^	3.56 (0.73) ^	3.85 (0.61) *	4.78 (0.12) ^
Decision Making	2.80 (0.33)	3.35 (0.35) ^	3.49 (0.54) ^	3.65 (0.61) *	4.70 (0.09) ^
Perioperative Care	2.53 (0.63)	3.25 (0.73) ^	2.80 (0.35) *	3.86 (0.61) ^	4.89 (0.13) ^
Intraoperative Issues	3.10 (0.31)	3.66 (0.32) ^	3.47 (0.53) ^	4.17 (0.58) ^	4.83 (0.09) ^
Recovery Room Issues	3.50 (0.69)	3.50 (0.52) *	3.40 (1.08) *	4.00 (0.76) *	5.00 (0.00) ^
Post-Operative Care	2.80 (1.01)	3.63 (0.50) ^	1.80 (0.42) ^	3.50 (0.53) *	5.00 (0.00) ^
Safety	3.01 (0.62)	3.34 (0.82) *	3.33 (0.69) *	4.09 (0.89) *	4.66 (0.22) ^
SDMRS (/25)	13.5 (2.19)	17.4 (2.42) ^	15.9 (3.51) ^	19.9 (2.70) ^	24.2 (1.17) ^
Anatomic Recognition	2.65 (0.49)	3.31 (0.70) ^	3.20 (1.03) *	4.13 (1.13) ^	4.75 (0.45) ^
Management of Current Task	2.70 (0.47)	3.56 (0.63) ^	3.00 (0.67) *	3.88 (0.64) *	4.88 (0.34) ^
Immediate Surgical Planning	2.60 (0.82)	3.56 (0.73) ^	3.10 (0.57) *	4.38 (0.74) ^	5.00 (0.00) ^
Avoidance of Complications	2.75 (0.72)	3.63 (0.72) ^	3.40 (1.08) *	3.50 (0.54) *	4.81 (0.40) ^
Higher Level Planning	2.80 (0.62)	3.31 (0.48) ^	3.20 (0.42) *	4.00 (0.00) ^	4.75 (0.45) ^
NOTSS – Categorical (/15)	7.95 (1.32)	10.4 (1.02) ^	8.90 (2.08) *	10.9 (0.99) *	13.1 (0.50) ^
Situational Awareness	2.70 (0.66)	3.56 (0.51) ^	3.20 (0.80) *	3.75 (0.46) *	4.06 (0.25) ^
Decision Making	2.70 (0.47)	3.69 (0.48) ^	2.70 (0.68) *	3.50 (0.54) *	4.13 (0.34) ^
Communication/Teamwork	2.55 (0.51)	3.13 (0.50) ^	3.00 (0.94) *	3.63 (0.52) ^	4.94 (0.25) ^

* Not statistically significant; ^ P-value <0.05; % P-value compares pre-test of seniors to juniors

Table 10.3 Knowledge, PSS, SDMRS, and NOTSS comparing Junior and Senior residents to experts.

PSS (Procedure Specific Score); MCQ (Multiple Choice Questions);
NOTSS (Non-Technical Skills for Surgeons); SDMRS (Surgical Decision-Making Rating Scale);

	PSS	SDMRS	Level	NOTSS	Marking	MCQ
PSS	1	0.917**	0.792**	0.881**	0.750**	0.712**
SDMRS	0.917**	1	0.759**	0.843**	0.736**	0.719**
Experience	0.792**	0.759**	1	0.685**	0.643**	0.242
NOTSS	0.881**	.843**	0.685**	1	0.736**	0.568**
Marking Score	0.750**	.736**	0.643**	0.736**	1	0.553**
MCQ Score	0.712**	.719**	0.242	0.568**	0.553**	1
Domains Cronbach's Alpha	0.963					
All Scores Cronbach's Alpha	0.979					
ICC (Each Rater)	0.574					
ICC (Between Raters)	0.977					

** P-value <0.001

Table 10.4 Correlation between level of experience, knowledge, PSS, SDMRS, and NOTSS
PSS (Procedure Specific Score); MCQ (Multiple Choice Questions);
NOTSS (Non-Technical Skills for Surgeons); SDMRS (Surgical Decision-Making Rating Scale);
ICC (Inter-class Correlation)

	Cognitive Item – Description
1	Awareness of the importance of accuracy of preoperative marks as the most important guide intra-operatively
2	Consider placing accurate marks while the patient is in the upright position or standing to guide intra-operative steps
3	Consider marking the midline, breast meridian (mid clavicle to the nipple) and current breast footprint
4	Consider marking 1.5 cm lateral to the midline to avoid dissection close to midline to avoid complications such as symmastia and bleeding
5	Awareness and respect to medial border (IMD > 3cm) to avoid complications such as symmastia and bleeding
6	Awareness that accurate symmetrical pocket planning is essential for success and can affect post-operative results in terms of symmetry breast proportions (Up: Lp)
7	Consider marking NS line at a maximal stretch (hands elevated at 45° above the horizon) to simulate optimal NAC position post-implantation
8	Consider basing pocket planning (superior and inferior borders) on the NS line at the midline for better results in terms of optimal NAC location postoperatively
9	Awareness and respect to the superior border based on NS line for symmetry and accuracy to avoid asymmetry and upper pole fullness
10	Awareness and respect to the inferior border based on NS line and new IMF for symmetry and accuracy to avoid asymmetry and lower pole fullness
11	Awareness of current and planned BW to take into account tissue thickness for optimal pocket design and avoiding pocket design > current BW
12	Consider more tight pocket designs with shaped and H>BW implants to avoid rotation (as compared to looser pockets with round implants)
13	Awareness and respect to symmetry and accuracy of the lateral border or pocket at the anterior axillary line to avoid asymmetry, wide cleavage and lateral malposition
14	Consider marking pocket design (superior, inferior, medial and lateral) using multiple dots and connecting them
15	Consider marking planned muscle release (dual plane) and muscle attachment release and new IMF and incision

Table 11.1 Cognitive items identified during the design phase used to design the curriculum and the Marking and Surgical Planning Scale (MSPS).

Marking and Surgical Planning Scale		
Rubric		Elements
5	Mentions most important points without prompting; able to explain reasoning; enhances safety	Breast Anatomy
4	Mentions most points with or without prompting, satisfactory; explains reasoning but with some difficulty	Implant Planning
3	Mentions some points with or without prompting; limited reasoning	Incision Planning
2	Does not mention; or does not know with prompting, no reasoning	Pocket Planning
1	Does not mention, gives wrong information; potentially endangers patient	

Table 11.2 Marking and Surgical Planning Scale (MSPS) – elements and assessment rubric – 4 elements, score (1-5), a maximum composite score of 20.

Participant characteristics	**All**	**Junior Residents**	**Senior Residents**	**Experts**
All	23 (100.0)	10 (43.5)	5 (21.7)	8 (34.8)
Age (Years) (P = <0.001)	35.7 (11.92)	28.7 (2.54)	30.2 (1.79) *	47.8 (13.4) ^
Male Gender – n (%) P = 0.862	20 (87.0)	9 (90.0)	4 (80.0)	7 (87.5)
Interview duration (Minutes) - μ (STD)	P = <0.001			43.6 (12.7)
Pre-test (P = <0.001)	36.6 (3.9)	32.7 (2.6)	38.9 (2.3)	P = 0.163
Post-test (P = 0.03)	42.5 (3.2)	40.9 (1.3)	46.5 (2.9)	P = 0.810
Self-Perception of PBA- (/10) μ (STD)				
Confidence (P = <0.001)	5.26 (3.86)	2.10 (1.52)	4.40 (3.13) ^	9.75 (0.71) ^
Comfort (P = <0.001)	5.35 (3.69)	1.90 (1.60)	5.40 (1.34) ^	9.63 (0.74) ^
Perception of importance - (/10) μ (STD)				
Psychomotor skills (P = 0.035)	8.96 (1.52)	8.20 (1.81)	8.80 (1.30) *	10.0 (0.00) ^
Cognitive skills (P = 0.032)	8.87 (1.21)	8.40 (1.27)	8.40 (1.14) *	9.75 (0.71) ^
Affective skills (P = 0.022)	8.52 (1.65)	8.00 (1.70)	7.60 (1.82) *	9.75 (0.46) ^
Past year experience with PBA (Performed P < 0.001 / Assisted P = 0.254) – (n %)				
None	11 / 7	9 / 5	2 / 2	0 / NA
1-5 Procedures	4 / 3	1 / 3	3 / 0	0 / NA
6-15 Procedures	4 / 4	0 / 2	4 / 2	4 / NA
> 26 Procedures	4 / 1	0 / 0	4 / 1	4 / NA

*Not statistically significant – Compared to Junior Residents
^ P Value <0.05 – Compared to Junior Residents

Table 11.3 Study participants with a comparison between senior and junior residents.
NOTSS (Non-Technical Skills for Surgeons); SDMRS (Surgical Decision-Making Rating Scale);
PBA (Primary Breast Augmentation)

Scores - μ (STD)	Junior Residents		Senior Residents		Experts
	Pre-Test	Post-Test	Pre-Test%	Post-Test	
All – n (%)	10 (43.5)		5 (21.7)		8 (34.8)
Exercises – n (%)	10 (26.3)	10 (26.3)	5 (13.2)	5 (13.2)	8 (21.1)
Marking Duration (Minutes)	8.10 (0.5)	8.20 (0.9) *	10.6 (0.9) ^	12.1 (0.7) ^	-
Marking Time (Seconds)	435.6 (311.8)	179.1 (88.1) ^	223.4 (152.4) ^	323.0 (378.1) *	276.5 (25.8) ^
Marking Moves (1000 Px)	2.67 (2.50)	2.71 (1.10) *	2.32 (1.80) *	4.46 (4.10) *	0.68 (6.03) ^
Marking Scores	10.4 (1.47)	16.0 (1.26) ^	13.5 (3.92) ^	14.8 (3.45) *	19.6 (0.51) ^
Breast Anatomy (5)	2.90 (0.64)	4.13 (0.62) ^	3.50 (0.53) ^	3.50 (1.31) *	4.88 (0.34) ^
Implant Planning (5)	2.35 (0.59)	4.14 (0.72) ^	3.52 (1.18) ^	3.88 (0.64) *	4.94 (0.25) ^
Incision Planning (5)	2.50 (0.51)	3.88 (0.34) ^	3.30 (1.06) ^	3.63 (1.06) *	4.81 (0.40) ^
Pocket Planning (5)	2.65 (0.59)	3.89 (0.34) ^	3.31 (1.42) ^	3.75 (0.71) *	4.94 (0.25) ^
Confidence in PBA Marking	1.33 (0.86)	3.06 (0.45) ^	1.22 (1.08) *	3.00 (0.23) *	-
Breast Anatomy (10)	4.30 (3.11)	8.00 (1.93) ^	3.60 (3.38) *	8.00 (1.31) *	-
Implant Planning (10)	3.20 (3.24)	7.75 (1.61) ^	3.00 (2.67) *	6.75 (1.39) *	-
Incision Planning (10)	4.30 (3.44)	8.63 (0.72) ^	3.00 (2.59) *	8.50 (0.54) *	-
Pocket Planning (10)	1.50 (1.23)	6.25 (3.72) ^	2.60 (2.46) *	6.75 (2.05) *	-
SDMRS (/25)	13.5 (2.19)	17.4 (2.42) ^	15.9 (3.51) ^	19.9 (2.70) ^	24.2 (1.17) ^
Anatomic Recognition	2.65 (0.49)	3.31 (0.70) ^	3.20 (1.03) *	4.13 (1.13) ^	4.75 (0.45) ^
Management of Current Task	2.70 (0.47)	3.56 (0.63) ^	3.00 (0.67) *	3.88 (0.64) *	4.88 (0.34) ^
Immediate Surgical Planning	2.60 (0.82)	3.56 (0.73) ^	3.10 (0.57) *	4.38 (0.74) ^	5.00 (0.00) ^
Avoidance of Complications	2.75 (0.72)	3.63 (0.72) ^	3.40 (1.08) *	3.50 (0.54) *	4.81 (0.40) ^
Higher Level Planning	2.80 (0.62)	3.31 (0.48) ^	3.20 (0.42) *	4.00 (0.00) ^	4.75 (0.45) ^

* Not statistically significant; ^ P-value <0.05; % P-value compares pre-test of seniors to juniors

Table 11.4 Marking attributes, MSPS, and SDMRS comparing Junior and Senior residents to experts

MSPS (Marking and Surgical Planning Score); SDMRS (Surgical Decision-Making Rating Scale);

	MSPS	SDMRS	Confidence	PGY Level
MSPS	1	0.736**	0.781**	0.643**
SDMRS - Overall	0.736**	1	0.705**	0.759**
Anatomic Recognition	0.644**	1	0.575**	0.678**
Management of Current Task	0.716**	1	0.677**	0.700**
Immediate Surgical Planning	0.680**	1	0.677**	0.695**
Complications Avoidance	0.646**	1	0.561**	0.629**
Higher Level Planning	0.670**	1	0.736**	0.768**
Marking Confidence	0.781**	0.705**	1	0.517**
Level of Experience (PGY)	0.712**	0.759**	0.517**	1
Domains Cronbach's Alpha	0.938			
All Scores Cronbach's Alpha	0.939			
ICC (Each Rater)	0.790			
ICC (Between Raters)	0.938			

* P-value <0.05 ** P-value <0.01

Table 11.5 Correlation between MSPS, SDMRS, Marking Confidence, and Level of experience (PGY Level)

MSPS (Marking and Surgical Planning Score); SDMRS (Surgical Decision-Making Rating Scale);
ICC (Inter-class Correlation); PGY (Post-graduate Year)

15.2 Figures

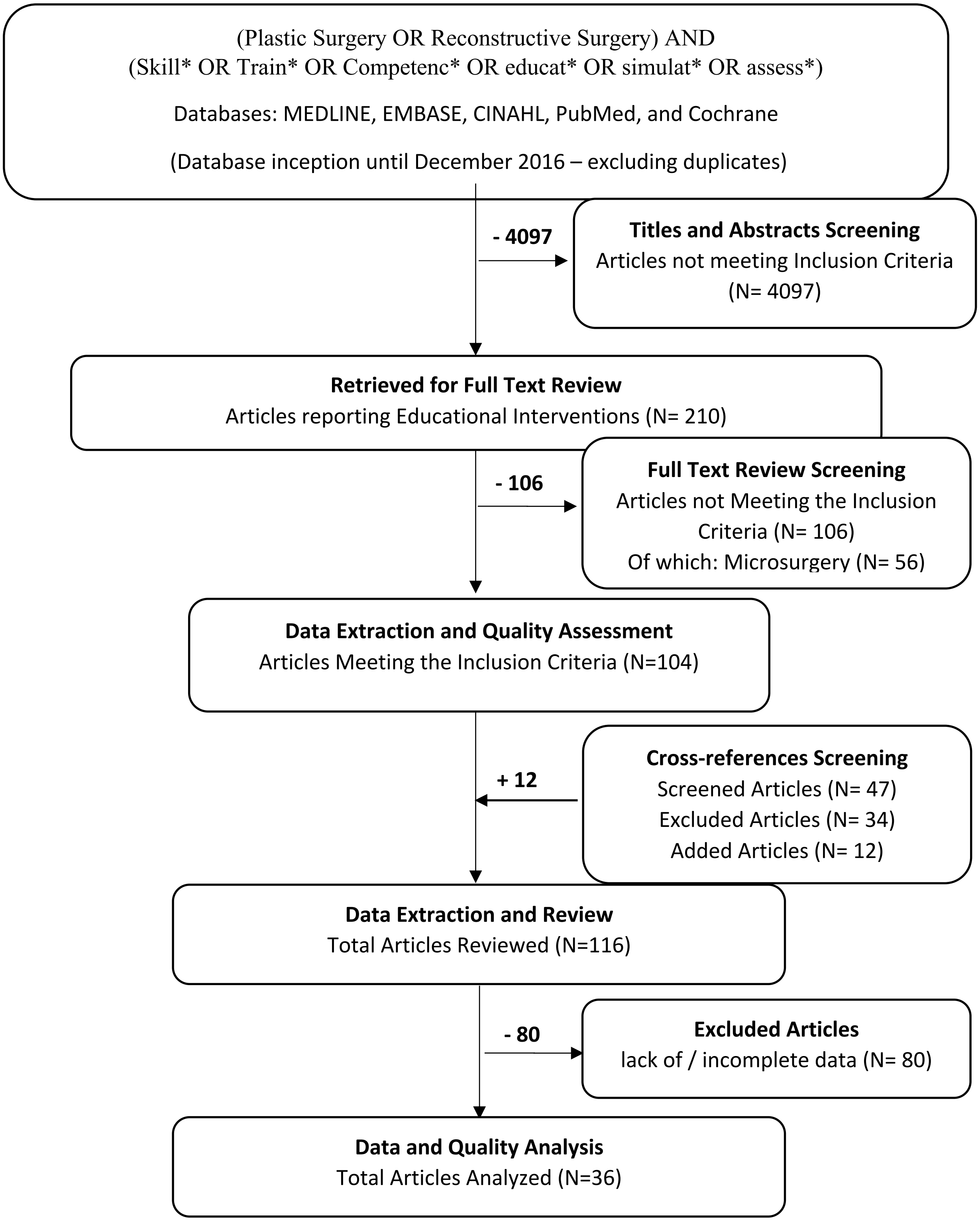

Figure 2.1 Flow chart representing the search methodology and results from MEDLINE, EMBASE, CINAHL, PubMed, and Cochrane databases.

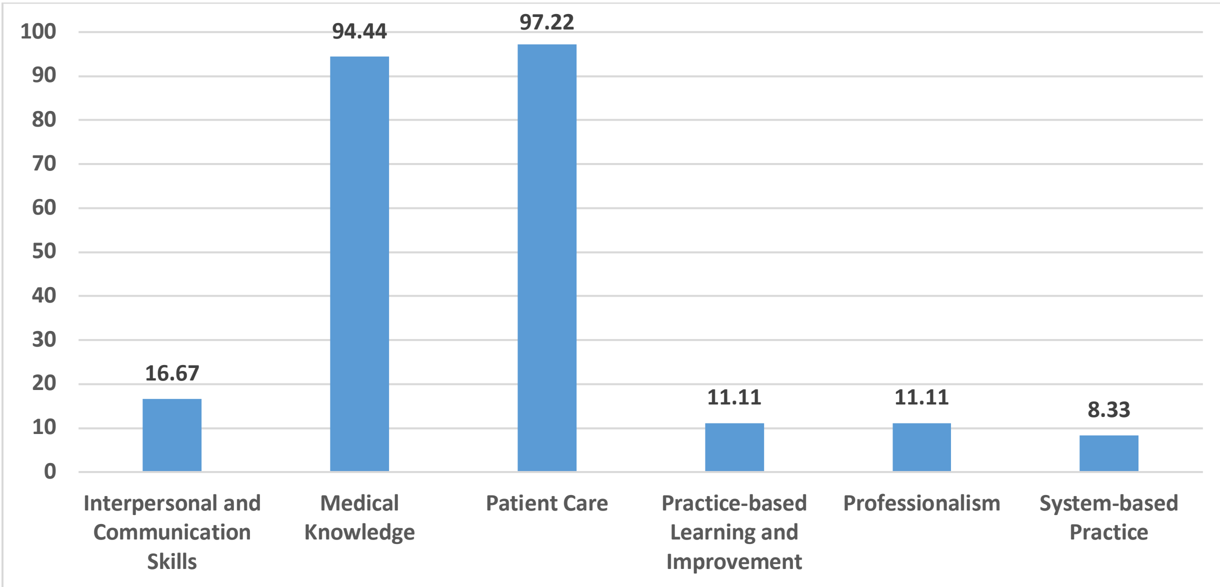

Figure 2.2 Percentage of Involvement of ACGME Competencies in 36 Included Educational Interventions

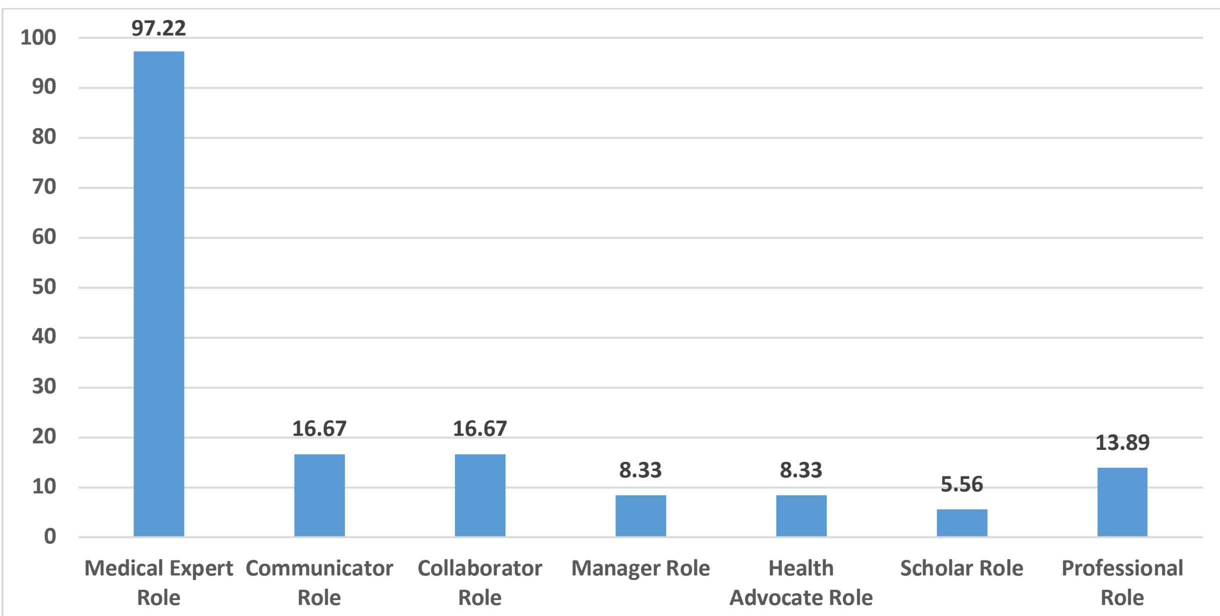

Figure 2.3 Percentage of Involvement of CanMEDs roles in 36 Included Educational Interventions

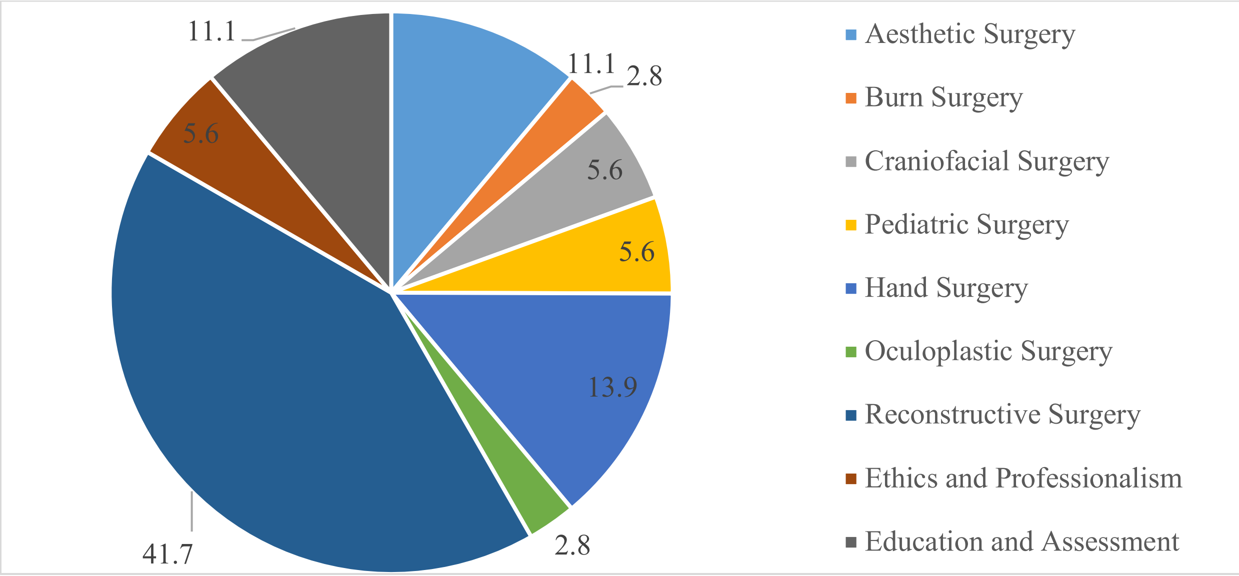

Figure 2.4 Distribution of the 36 Included Educational Interventions by the involved sub-specialty

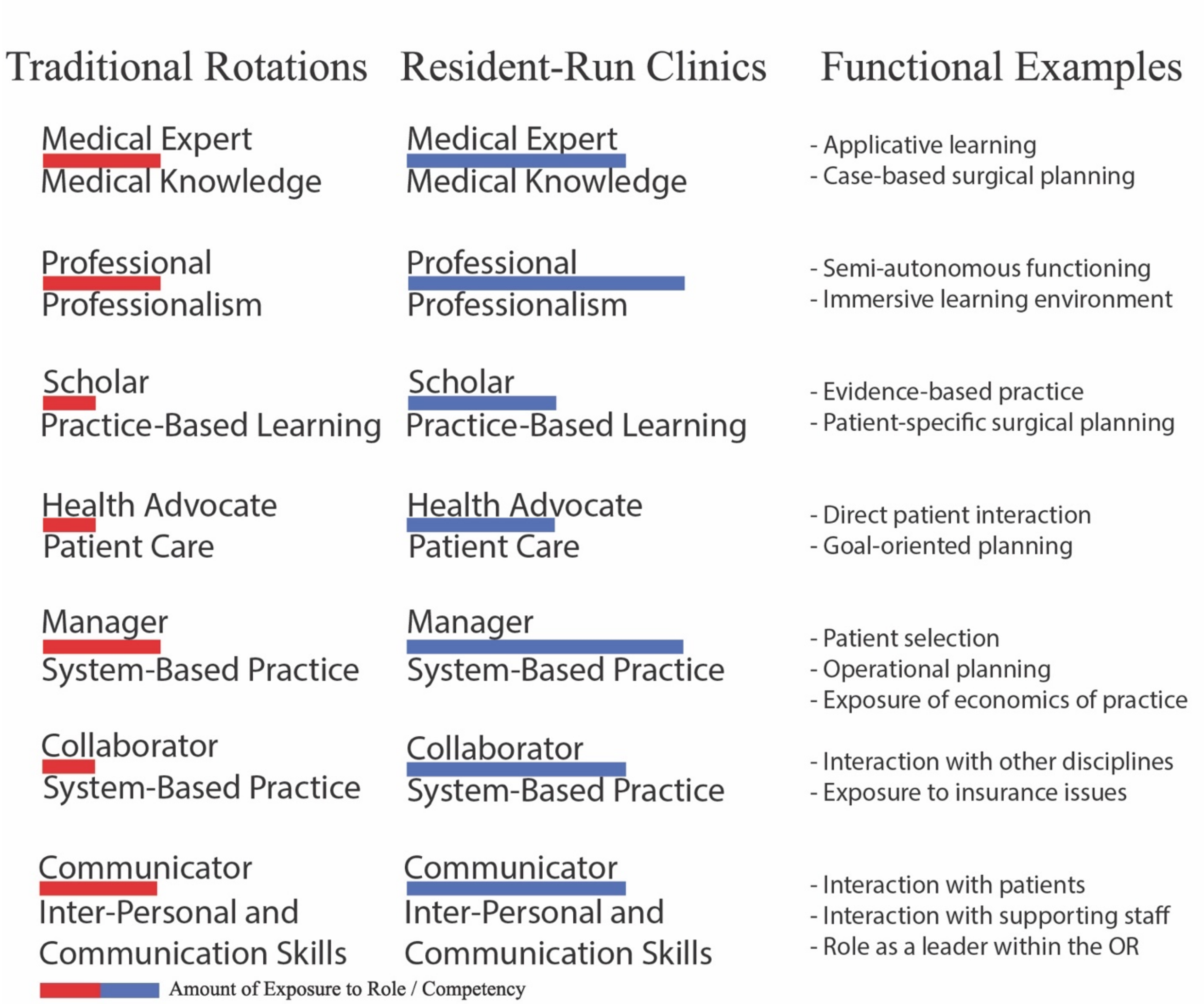

Figure 4.1 Comparison of Traditional Aesthetic Training and Resident Run Aesthetic Clinics

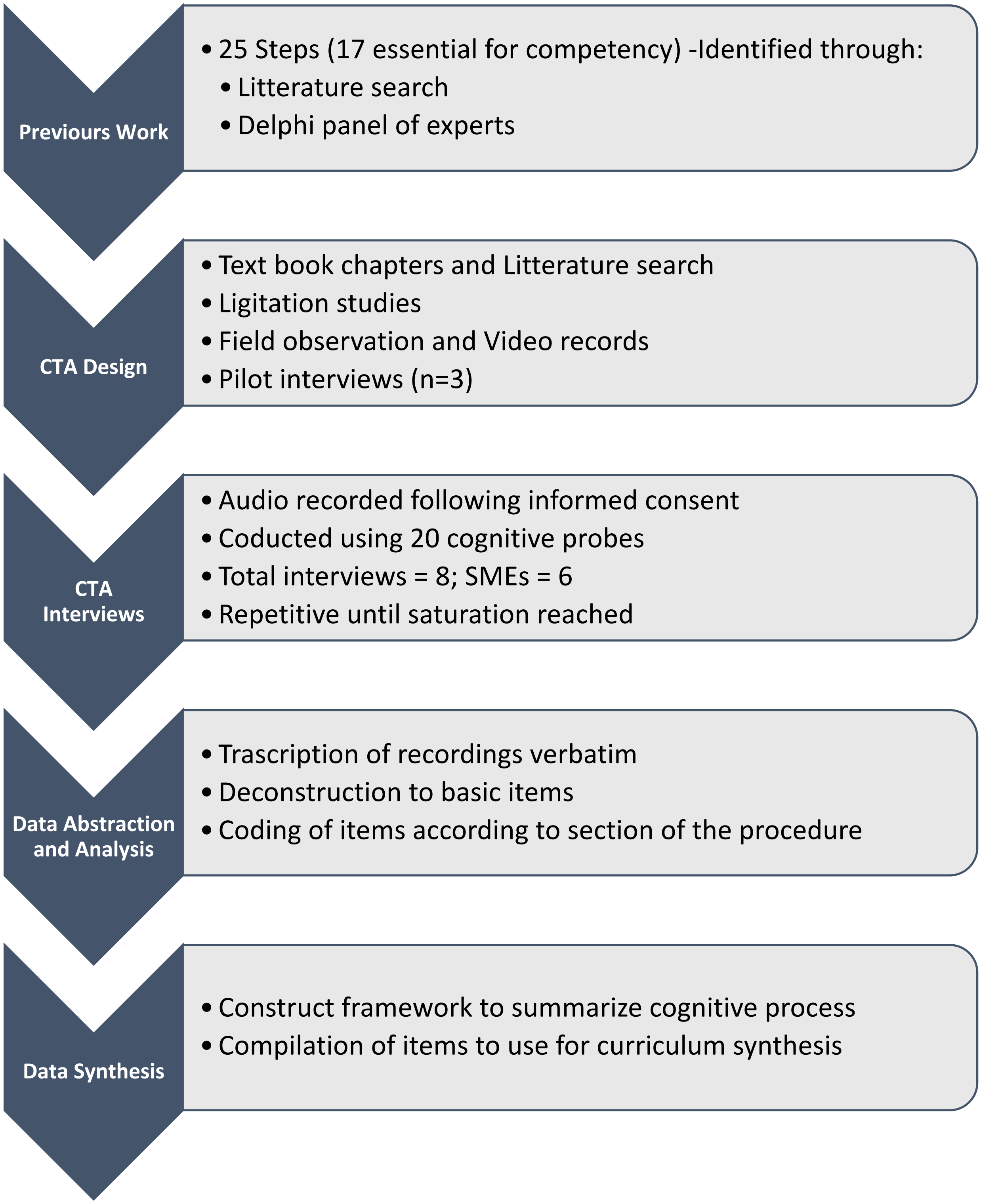

Figure 6.1 Flowchart demonstrating the overall methodology of the study to identify cognitive competencies within breast augmentation procedure.
CTA – Cognitive task analysis; SME – Subject matter experts

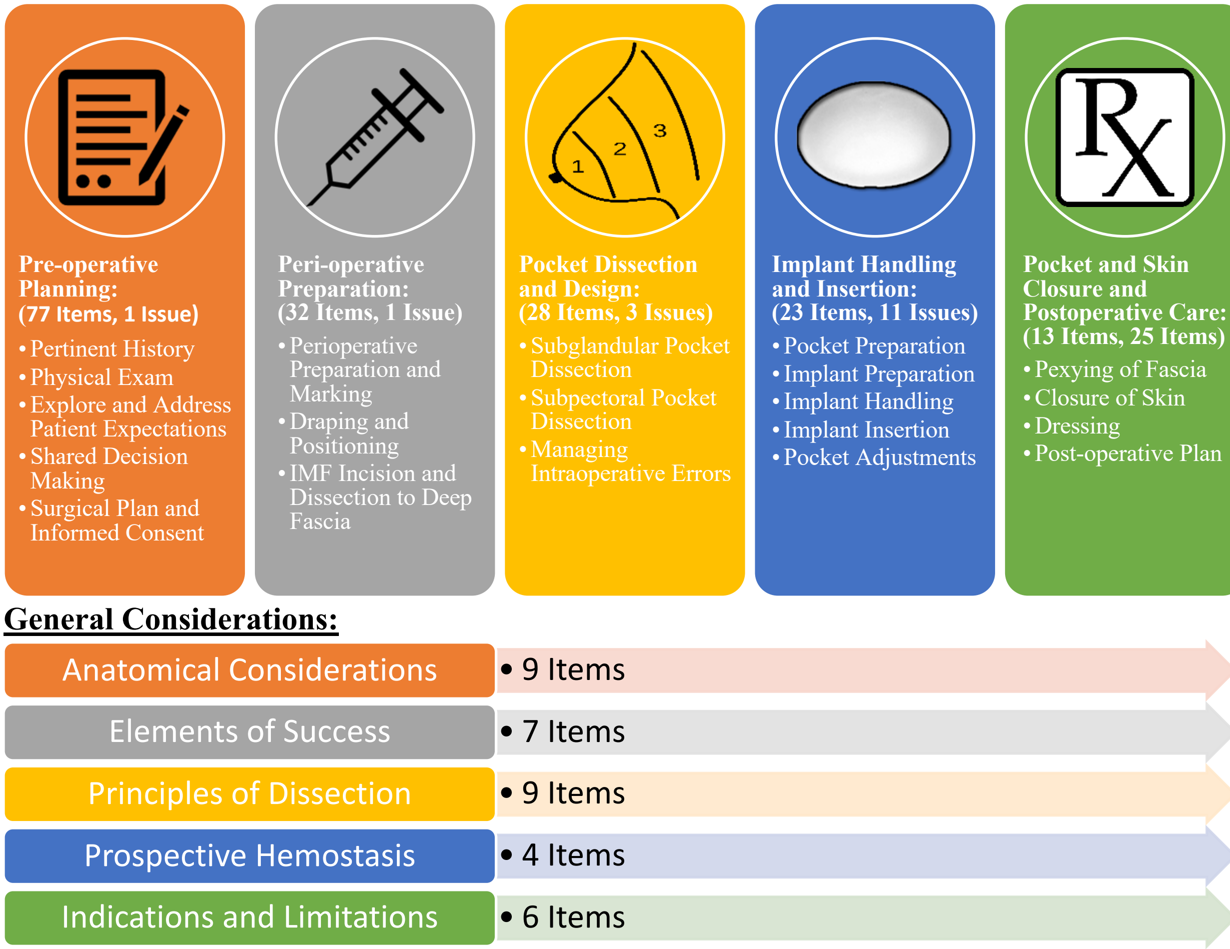

Figure 6.2 A conceptual framework to map identified cognitive competencies in primary breast augmentation (208 items and 41 issues and complications).

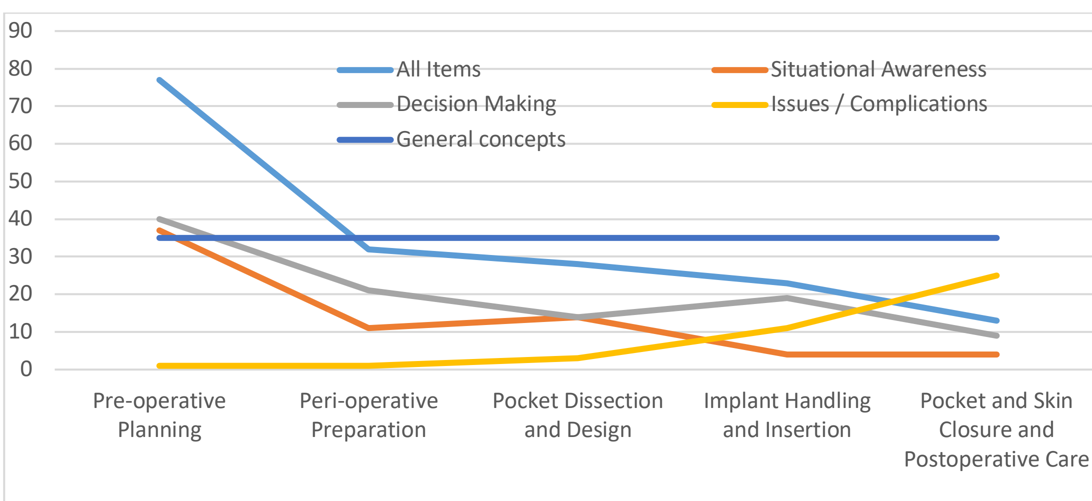

Figure 6.3 Identified cognitive items, classified by type, and issues and complications by section of the procedure (208 items and 41 issues and complications).

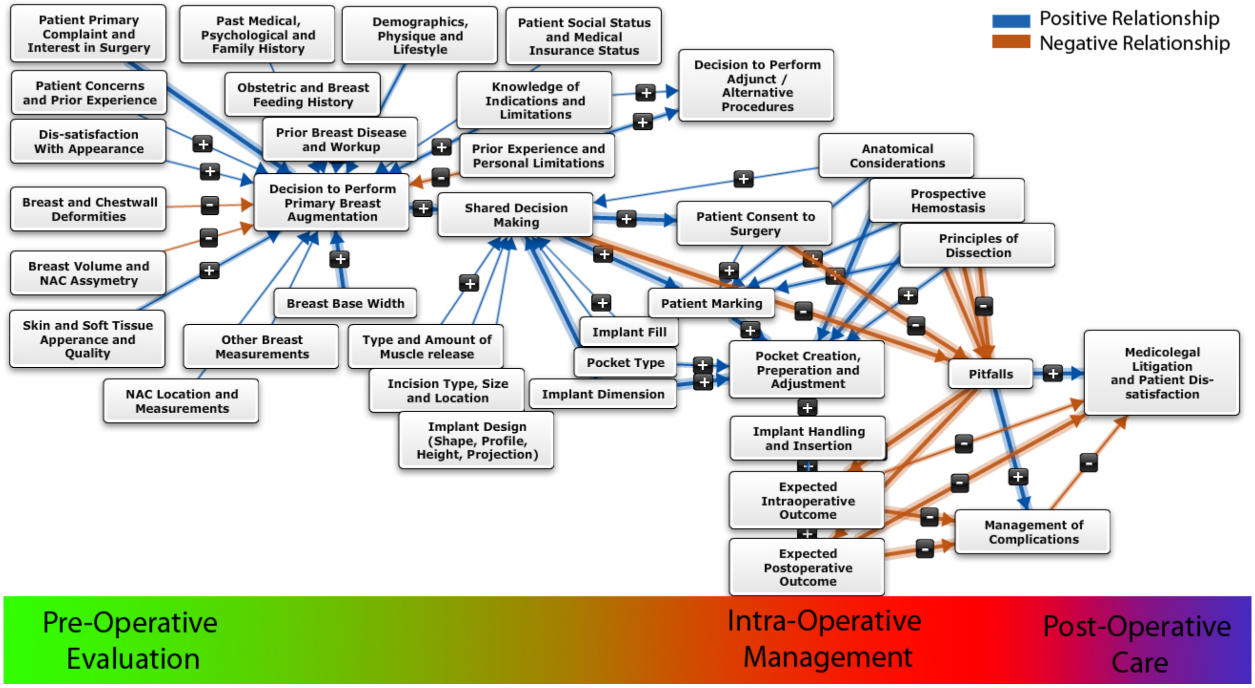

Figure 8.1 Synthesized mental model for experts thinking in primary breast augmentation using data from cognitive task analysis for safety and success of primary breast augmentation.

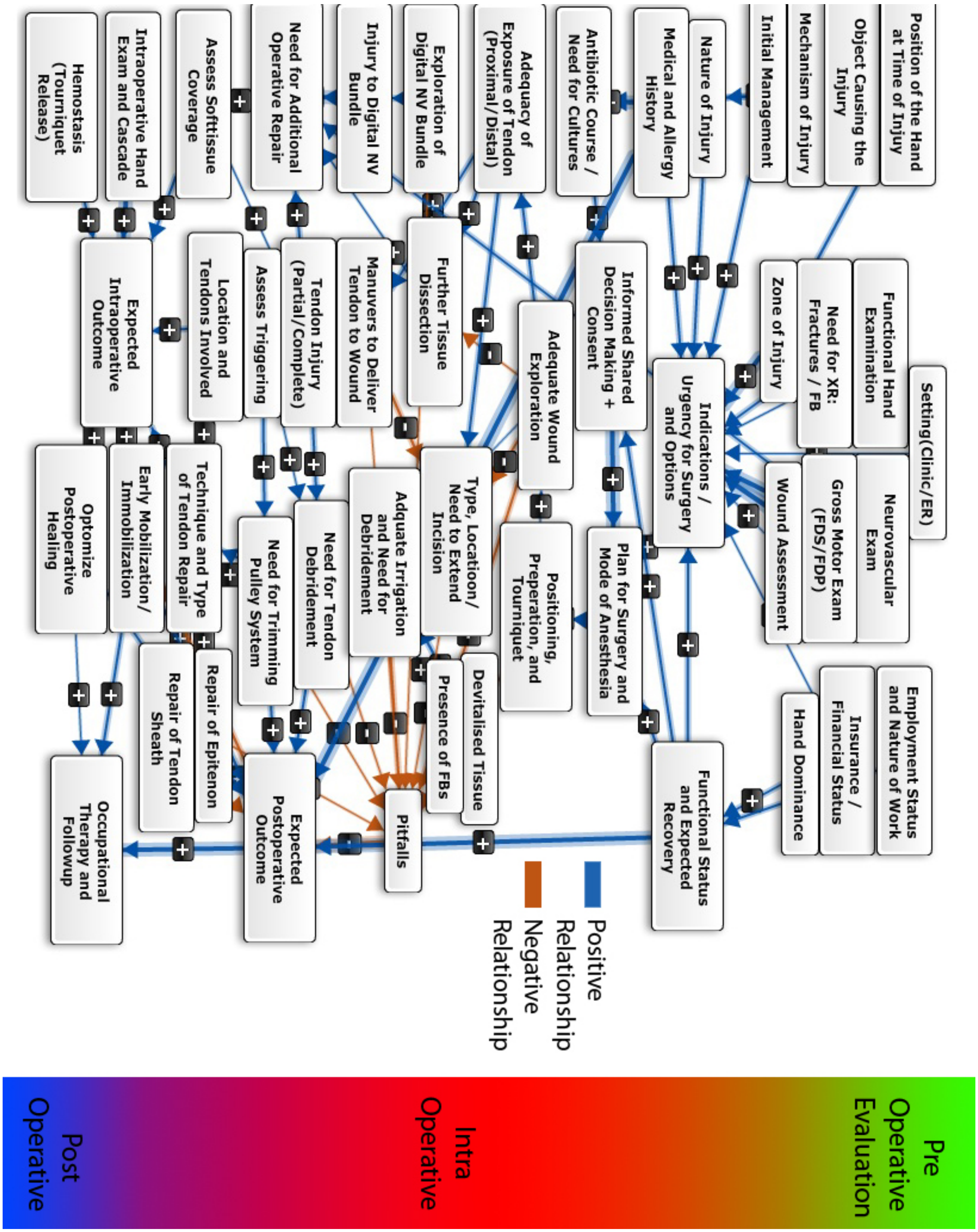

Figure 8.2 Synthesized mental model for experts thinking in primary breast augmentation using data from cognitive task analysis for safety and success of primary breast augmentation.

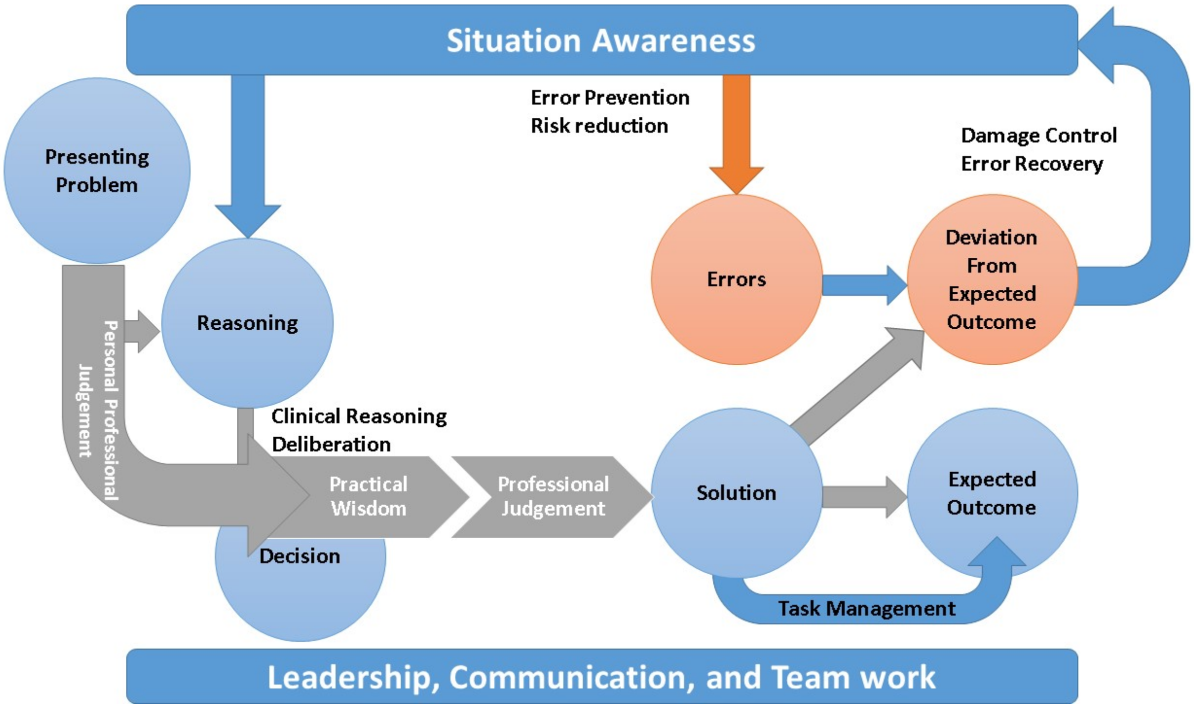

Figure 8.3 The synthesized framework of the application of cognitive competencies within a generic mental model for experts thinking in surgical care

ID	Title	Description	Duration	Status
	Pre-Mark	Patient marking to be done PRIOR to starting the modules	5-10 Minutes	Incomplete Mark Patient
	Pre-Test	Twenty MCQ's (20) to be done PRIOR to starting the modules	10-15 Minutes	Incomplete Solve Questions
	Pre-Operative	This module focuses on pre-operative patient assessment for breast augmentation including the initial encounter, and surgical planning.	15-20 Minutes	Incomplete Start Module
	Surgical Judgement	What decisions are you making intra-operatively? Are you aware of these decisions? How can you evade trouble?	25-30 Minutes	Incomplete Start Module
	Implant Selection	Can three implants have the same volume? What is the difference between projection and profile?	35-40 Minutes	Incomplete Start Module
	Safety	An essential component of competence is safety, how can you proceed safely through your procedure? What if things go differently than you expected?	30-35 Minutes	Incomplete Start Module
	Marking / Perception	Are these pre-operative marks important? Do all surgeons mark the same way? How do they help you intra-operatively?	20-25 Minutes	Incomplete Start Module
	Post-Test	Twenty MCQ's (20) to be done AFTER doing the modules	10-15 Minutes	Incomplete Solve Questions
	Post-Mark	Patient marking to be done AFTER doing the modules	5-10 Minutes	Incomplete Mark Patient
	Feedback	System Feedback to be done AFTER doing the modules	5-10 Minutes	Incomplete Give Feedback

Figure 10.1 Screenshot of the web-based interactive curriculum developed for this study with 5 modules to teach cognitive competencies of Breast Augmentation.

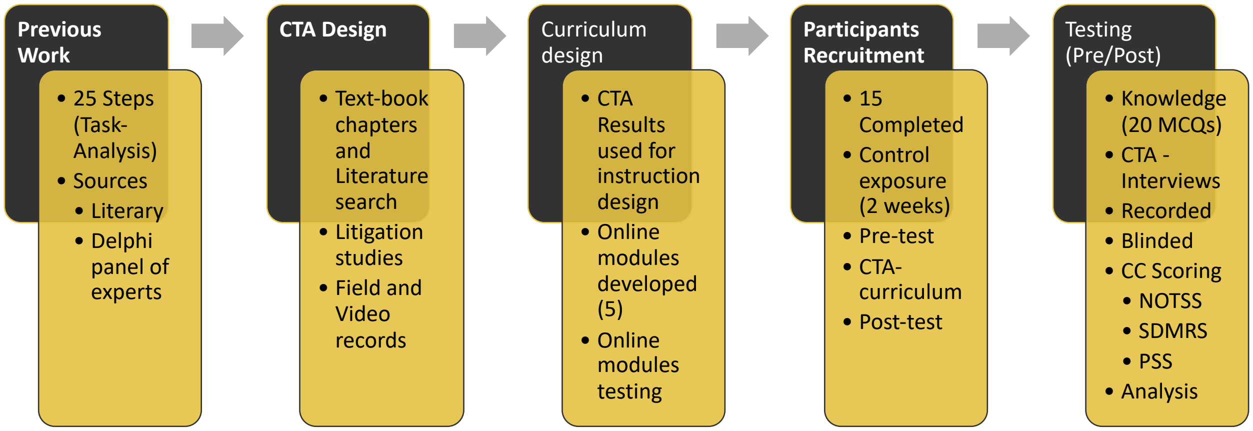

Figure 10.2 Flowchart demonstrating the overall methodology of the study to identify, teach and assess cognitive competencies of Breast Augmentation.

CTA (Cognitive Task Analysis); PSS (Procedure Specific Score); MCQ (Multiple Choice Questions);

NOTSS (Non-Technical Skills for Surgeons); SDMRS (Surgical Decision-Making Rating Scale);

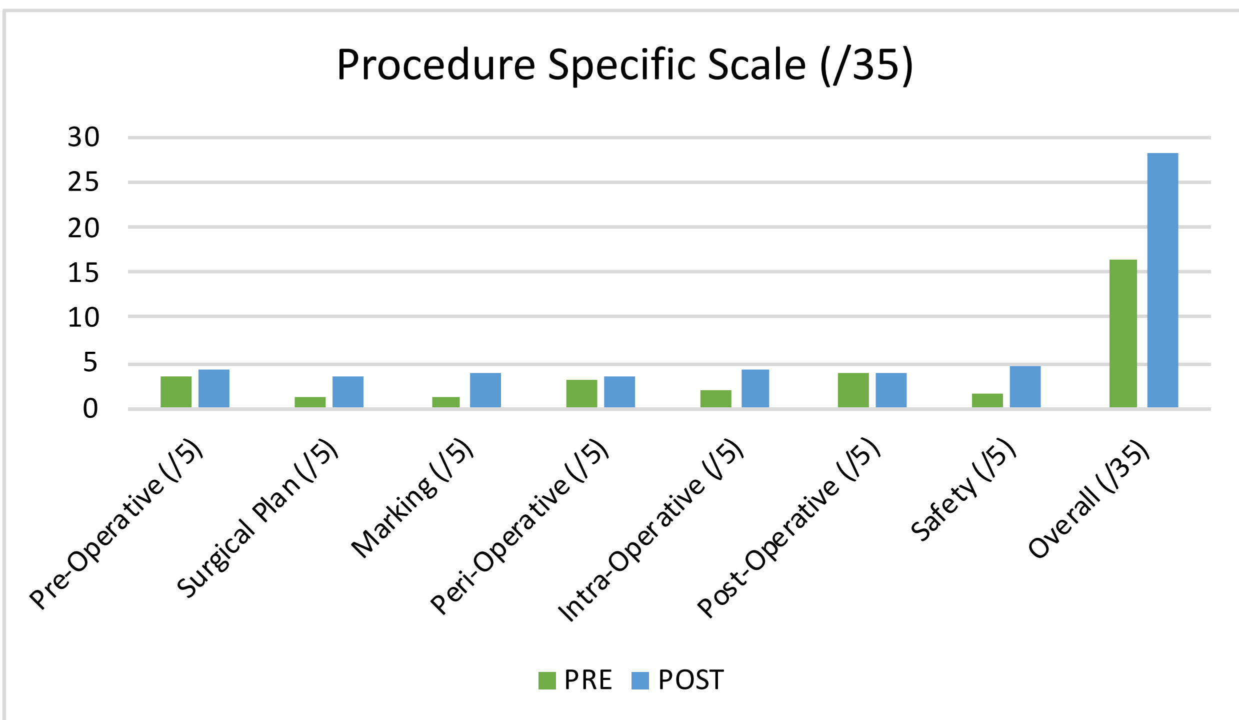

Figure 10.3 Procedure Specific Scale (PSS) per Domain comparing pre- and post-test scores.

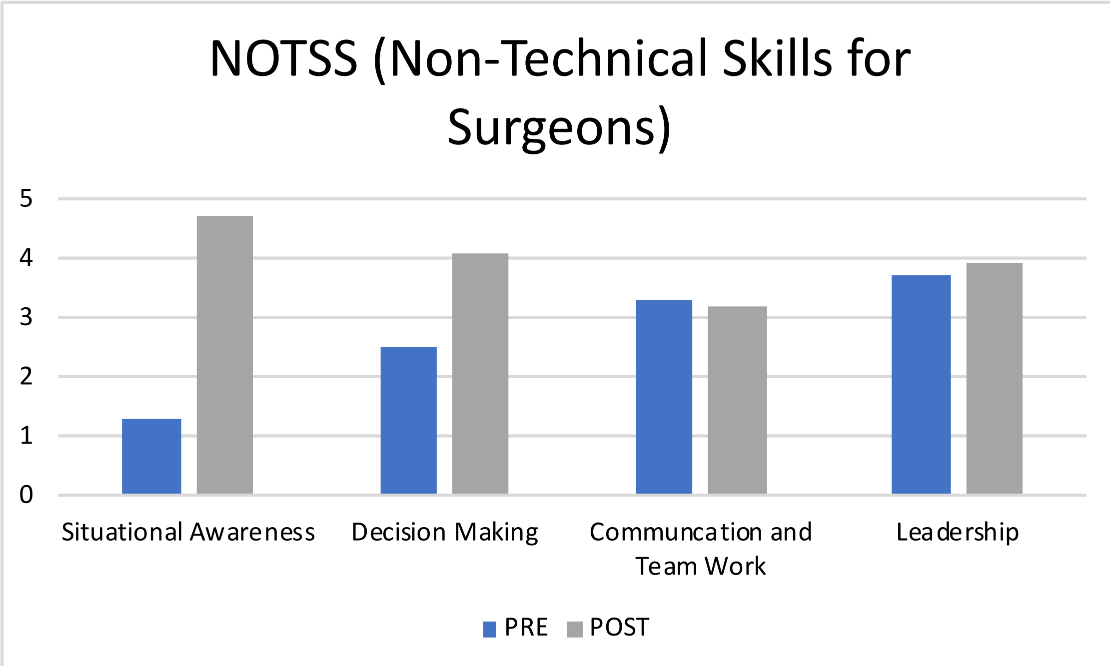

Figure 10.4 Non-Technical Skills for Surgeons (NOTSS) scale comparing pre- and post-test scores.

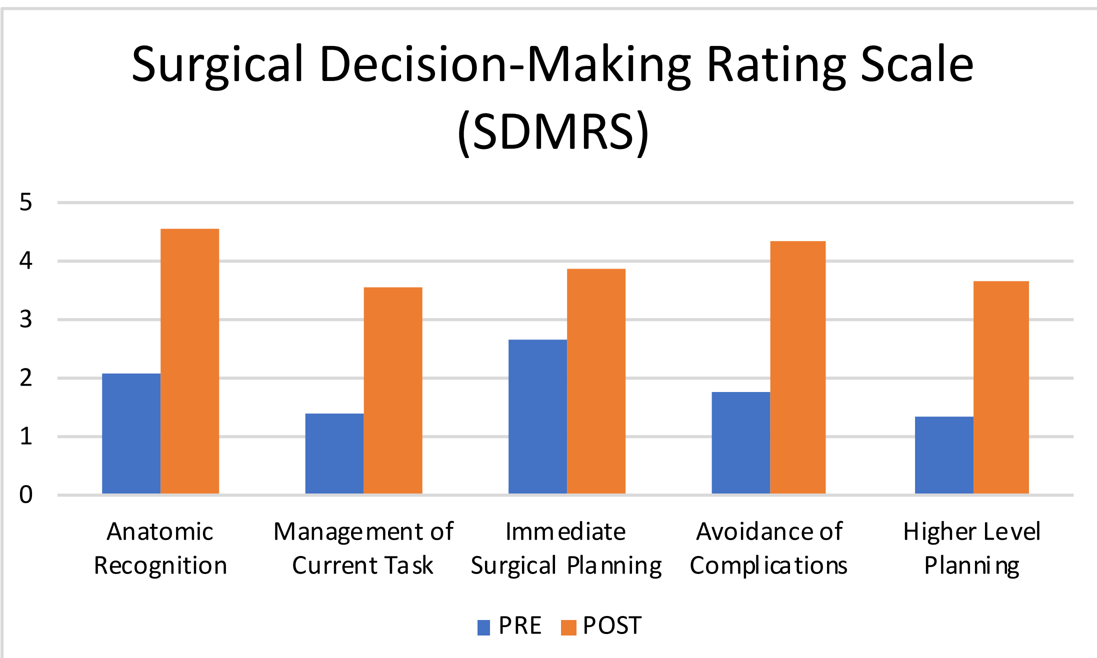

Figure 10.5 Surgical Decision-Making Rating Scale (SDMRS) per Domain comparing pre- and post-test scores.

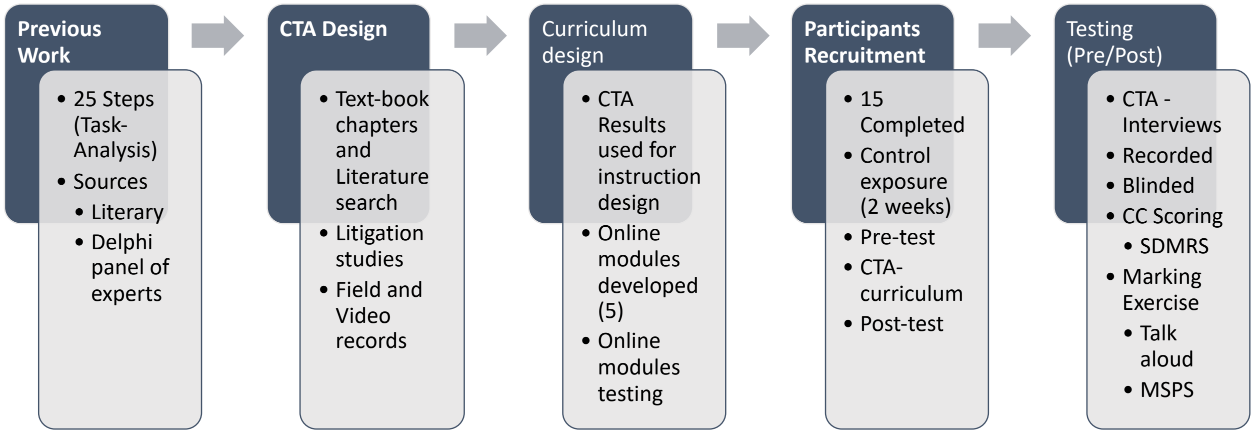

Figure 11.1 Flowchart demonstrating the overall methodology of the study to identify, teach and assess cognitive competencies of Breast Augmentation including perception and marking.

CTA (Cognitive Task Analysis);

SDMRS (Surgical Decision-Making Rating Scale); MSPS (Marking and Surgical Planning Score);

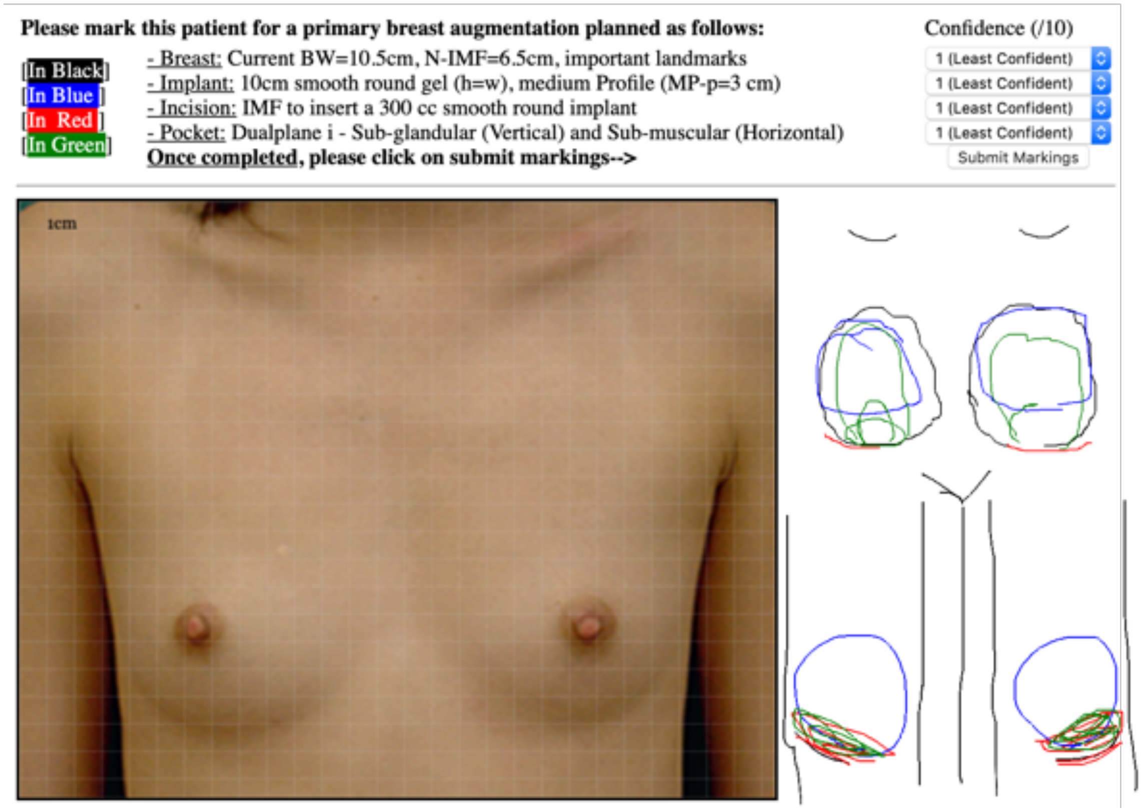

Figure 11.2 Screenshot of the web-based interactive marking exercise developed for this study with 4 components to assess pre-operative marking of Breast Augmentation with sample responses and markings done by residents at various levels of experience prior to (above) and following exposure to the intervention.

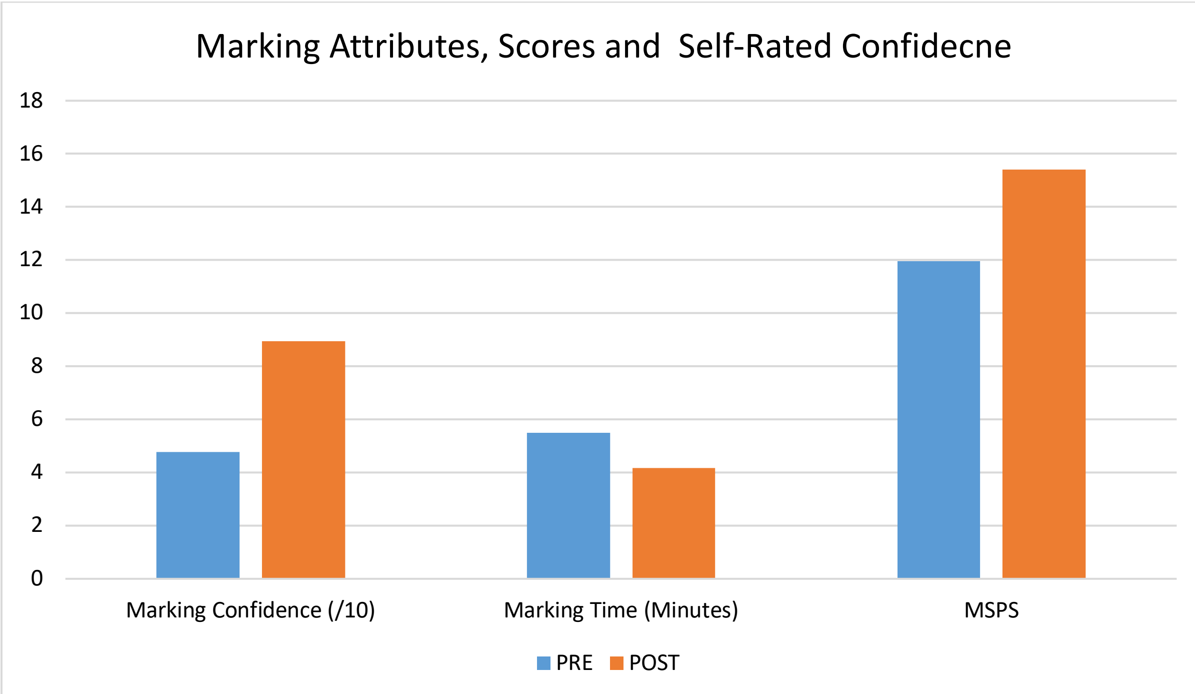

Figure 11.3 Marking attributes and MSPS comparing pre- and post-test scores.

MSPS (Marking and Surgical Planning Score);

15.3 Appendices

General Considerations

Anatomical Considerations (N = 9 items):	
A1	Awareness of degree of anatomical asymmetries in terms of breast volume and NAC
A2	Awareness of tuberous breast / lower pole deformities for effective planning
A3	Awareness of exaggeration effect of augmentation post-operatively on asymmetries
D1	Consider adjunct procedures in deformities, asymmetry in volume or NAC, and ptosis
D2	Use of objective assessment systems (e.g. Tebbet's) for breast measurements
A4	Awareness that breast tissue is rich in perforators and anticipation of major perforators
A5	Awareness of chest deformities in Poland syndrome, pectus excavatum, rounded thorax, and spine deformities (Scoliosis) to account for repair and consider in decision making
D3	Consider adjustments and adjunct surgeries in chest and spine deformities
A6	Awareness of fibrous muscle insertions in the tuberous breast to reduce the risk of complications
Elements of Success (N = 7 items):	
A7	Awareness of volume, envelop, symmetry, proportions, chest wall and patient expectations
D4	Consider objective pre-operative planning for accurate marking to guide dissection
D5	Consider respect of breast boundaries and performing a clean meticulous pocket dissection
A8	Awareness asymmetries prior to dissection, and following dissection and implant insertion
D6	Consider proper implant handling and insertion with minimal touch and proper closure
D7	Consider avoiding high volume implants to reduce complications (>350-400cc)
D8	Consider self-professional development, assessment and update and outcome-based practice
Principles of Dissection (N = 9):	
A9	Awareness of breast boundary and pre-operative markings to assure symmetry in dissection
D9	Consider adequate retraction to allow for visualization of the dissection plane
D10	Consider use of electrosurgical instruments to dissect pocket – avoid blunt/sharp dissection
D11	Consider use of blend mode for efficient cutting and coagulation without tissue charring
A10	Awareness of correct dissection plane to avoid deep dissection and malposition
D12	Consider prospective mindset with bloodless pocket dissection and avoiding tissue trauma
D13	Consider avoidance of tissue trauma and bleeding during dissection
D14	Consider pocket dissection in the sequence of least tension to avoid trauma and deep dissection
D15	Consider the use of special equipment to assist in exposure and reduce operative time
Prospective Hemostasis (N = 4 items):	
A11	Awareness of perforators anatomy, intramuscular vessels, and areas of major perforators
D16	Consider cauterizing visible perforators effectively to avoid vessel withdrawal
A12	Awareness of underlying vessels during retractor relocation to avoid inadvertent injury
D17	Consider cauterizing perforators at 3 locations to avoid stump bleeding / postop hematomas
Indications and Limitations (N = 6 items):	
A13	Awareness of indications, such as hypo-mastia, involution of the breast, and patient preference
A14	Awareness of limitations to correct mild asymmetries and plan required adjunct procedures
D18	Consider factors such as puberty, weight loss, gravidity and lactation in delaying surgery
D19	Consider avoiding surgery for unrealistic expectations and surgical/psychological CI
A15	Awareness of the risk of smoking, diabetes, and history of radiation therapy on skin quality
D20	Consider delaying surgery until patient quits smoking or skin quality improves

Appendix 1. Summary of 35 items for subthemes within general considerations synthesized after 5 rounds of data analysis for the success of primary breast augmentation.
A (Situation awareness); D (Decision-making); NAC (Nipple areola complex); CI (Contra-indications)

Pre-operative Preparation

Pertinent History (N – 4 items):	
A16	Awareness of age, breast maturity, lifestyle, social, psychiatric and cosmetic history, and weight loss
A17	Awareness of psychological stability and body dysmorphia
A18	Awareness of obstetric and breast-feeding history and family planning
A19	Awareness of breast disease history, the workup for pathologies, and family history
Physical Examination (N = 9 items):	
A20	Awareness of body habitus, breast shape and proportions and skin colour and contour
A21	Awareness of breast measurements including N-S, N-IMF, BW, APSS, STPT-UP, and STPT-IMF as factors contributing to implant selection (volume, new IMF and profile)
D21	Considering BW as the most important element in implant selection to decrease reoperations
A22	Awareness of NAC size, shape and symmetry and need for adjunct/alternate procedure
A23	Awareness of skin pinch test (upper + lower pole) and anterior pull test (envelop)
A24	Awareness of skin and tissue quality, stretch marks, ptosis, and amount of muscle bulk
D22	Consider breast and lymph node exam to the workup any suspicious lesions pre-operatively
A25	Awareness of pectoralis muscle bulk pre-operatively (press hands on the sides)
A26	Awareness of postpartum tissue atrophy (elasticity) - avoid the risk of late lower pole descent
Exploring and Addressing Patient Expectations (N = 8 items):	
A27	Awareness of patient education, occupation, knowledge on the procedure (previous consults)
D23	Consider exploring primary complaint, objectives, and plans for further cosmetic surgery
D24	Consider use of sizers, rice baggies test, and 3D software to simulate expected outcome
D25	Consider patients to simulate various settings, styles of cloth and obtain others advice
A28	Awareness of limitation of expected results and that results cannot be guaranteed
A29	Awareness that 3D software might not take all elements (skin + soft tissue) into account
D26	Consider addressing unrealistic requests of implant/incision size, and IMF (cleavage)
D27	Consider denying care under unrealistic expectation <u>OR</u> consent for complication risk
Shared Decision Making (N = 43 items):	
A30	Awareness of the envelope, parenchyma, and implant as 3 elements of decision making
D28	Consider objective pre-operative assessment systems - no evidence of change in outcome
D29	Consider patient desire as most important in decision making and satisfaction guarantee
A31	Awareness to monitoring silent ruptures and silicone implants effect on mammography
D30	Consider saline fill limitations of plane, shape, texture, ptosis correction and aesthetics
D31	Consider saline resizable implants for size adjustment in reconstruction, asymmetry, etc
D32	Consider round implants limitations of natural appearance and upper: lower pole ratio
A32	Awareness of inadequate tissue coverage where round implants are used (UP-STPT <2 cm, or 1 cm at any point) – due to the risk of rippling
D33	Consider anatomical implants in thin patients, for superior aesthetics, addressing mild asymmetries, following CC, and to prevent upper pole collapse (form stable implants)
A33	Awareness of the risk of rotation in shaped implants and if BW ≠ H
D34	Consider BW ≤ current patient BW in size selection (most critical to preserve coverage)
D35	Consider BW > current BW if < 10 cm or in lower pole constriction (tuberous breast)
D36	Consider 275-325 cc in most cases and allow patient to provide feedback on preference
D37	Consider higher profile implants in petite physique, thin tissue, and narrow chest wall
D38	Consider moderate profile if adequate volume, wide chest, wide IMD, and tall patients
D39	Consider form stable implants for versatility, mild ptosis, prevent upper pole collapse and tuberous breasts
D40	Consider lower height implants if S-N <19 or height is <5', moderate height implants if the height is 5'-5'7"
D41	Consider full height implants if S-N <19 (a better reflection of body proportions) or height is >5'7"
D42	Consider full projection implants in glandular atrophy, excess skin, or APSS >3 cm to achieve lift effect
A34	Awareness of APSS <3 cm - lack of skin envelop compliance to avoid excessive volume
A35	Awareness of the risk of migration and lack of predictability with smooth implants
D43	Consider smooth implants - better edges fill if weak tissue coverage (Subglandular plane)

D44	Consider textured implants for stability and avoid rotation (shaped implants / BW > H)
A36	Awareness that the risk of ALCL and CC is higher in textured implants
D45	Consider sub-glandular pocket if sufficient breast tissue and adequate coverage (UP-STPT >2 cm, 1 cm any)
A37	Awareness of compromise of UpP contour, visibility and palpability of implant with sub-glandular pockets
A38	Awareness of the higher risk of capsular contracture in sub-glandular plane
D46	Consider sub-pectoral pocket in thin patients, inadequate tissue coverage (UP-STPT >2 cm, or 1 cm at any point), saline implants or trans axillary approach, or patient preference
A39	Awareness of the increased postoperative pain caused by muscle dissection and risk for animation and lateral auto-dissection of the pocket while using sub-pectoral pockets
A40	Awareness of sub-fascial plane as an alternative to sub-pectoral, but uncommonly used to gain reduction in CC with less muscle dissection, very thin, tedious to dissect, and bleeds
D47	Consider lowering IMF in almost all patients based on implant BW and current N-IMF for better breast proportions, address asymmetries, or to release and score the lower pole
A41	Awareness of implant height and breast curvature (TEPID system), implant volume, and nipple location at the maximal stretch to guide the lowering of IMF
D48	Consider inframammary incisions in patients with small areolar diameter, ptosis or status postpartum, when using larger implants and to allow for better visualization and exposure
A42	Awareness of ↓upper pole exposure, scar, and implant injury risk with IMF approach
A43	Awareness of the risk of implant extrusion in patients with inadequate soft-tissue coverage
A44	Awareness of other incisions, indications, advantages, and limitations
D49	Consider IMF incision 0.5cm below <u>OR</u> on new-IMF to hide it (scar ↑0.5cm in 6 months)
D50	Consider an incision 1/3 medial to medial nipple edge, and 2/3 lateral (4.5 - 5 cm)
D51	Consider longer incisions for form stable / large implants and smaller resizable implants
D52	Consider excess muscle dissection at fascia (dual plane) to allow for more tissue coverage in ptosis for lifting breasts (type II), or lower pole constriction (type III)
A45	Awareness of difference between dual plane and complete sub-muscular and risk for morbidity with sub-muscular pocket due to limited lower pole expansion
D53	Consider thinning out pectoralis insertion to reduce risk of lateral auto-dissection and to ↓ IMD
A46	Awareness of symmastia and bleeding risk with medial dissection of sternal attachments
Surgical Plan and Informed Consent (N = 13 items)	
D54	Consider basic workup including EKG, basic blood work, +/- CXR
D55	Consider further workup, such as an anesthesia consult, and workup of breast findings
D56	Consider ordering of triplets of implants pre-operatively (size of choice +/-) + equivalent sizers
A47	Awareness of informed consent importance on reducing the risk of litigations in breast augmentation
D57	Consider written documentation of all joint decisions made with the patient, type of procedure and anesthesia, available alternative, risks and complications and possible need for revision
D58	Consider ensuring patient understanding and addressing any concerns
A48	Awareness of the need to clarify objectives to avoid unmet expectations as a risk for litigation
D59	Consider use of aids and pictures to demonstrate and document choices made by the patient
A49	Awareness of the need to explain all available alternative to avoid litigations based on overtreatment
A50	Awareness of average reoperation rate (~5%) caused mainly by CC, size change, deflation, malposition, and early complications and need to disclose additional costs of such complication
A51	Awareness of the need to disclose all scenarios for a full recovery to avoid claims on delayed recovery
A52	Awareness of the need to document all pre-operative findings and asymmetries to avoid litigations
D60	Consider digital documentation of all finding with consented digital photography

Appendix 2. Summary of 77 items for sub-sections within pre-operative planning synthesized after 5 rounds of data analysis for the success of breast augmentation.

A (Situation awareness); D (Decision-making); NAC (Nipple areola complex); N-S (Nipple-Sternal); N-IMF (Nipple-Inframammary fold); BW (Base width); APSS (Anterior pull stretch test); STPT-UP (Soft tissue pull test - Upper pole); STPT-IMF (Soft tissue pull test – At inframammary fold); ALCL (Anaplastic large cell lymphoma); CC (capsular contracture); UpP (upper pole); LoP (lower pole);

Peri-operative Preparation

Perioperative Preparation and Marking (N = 19 items)

A53	Awareness of the need to confirm patient consent on the day of surgery and to assume surgery mindset
D61	Consider rechecking of shared decisions and signature of informed consent with the patient
D62	Consider checking the availability of implants and confirm size and settings conform to decisions
D63	Consider cancelling or rescheduling procedure if implants were not available or of wrong settings
A54	Awareness of the accuracy of preoperative marks as the most important intra-operative guide
D64	Consider placing accurate marks while the patient is in the upright position or standing
D65	Consider marking midline, breast meridian (mid clavicle to the nipple) and current breast footprint
D66	Consider marking 1.5cm lateral to the midline to avoid dissection risking symmastia and bleeding
A55	Awareness and respect to the medial border (IMD > 3cm) to avoid symmastia and bleeding
A56	Awareness that accurate symmetrical pocket planning is essential for success and can affect post-operative results in terms of symmetry breast proportions (Upper pole: Lower pole)
D67	Consider marking NS line at the maximal stretch (hands elevated at 45º above the horizon) to simulate optimal NAC position post-implantation
D68	Consider basing pocket planning (superior and inferior borders) on the NS line at the midline for better results in terms of optimal NAC location postoperatively
A57	Awareness to the superior border based on NS line to avoid asymmetry and upper pole fullness
A58	Awareness to the inferior border based on NS line and new-IMF to avoid asymmetry or lower pole fullness
A59	Awareness of current and planned BW to take into account tissue thickness for optimal pocket design and avoiding pocket design > current BW
D69	Consider more tight pocket designs with shaped and H>BW implants to avoid rotation
A60	Awareness and respect to symmetry and accuracy of the lateral border or pocket at the anterior axillary line to avoid asymmetry, wide cleavage and lateral malposition
D70	Consider marking pocket design (superior, inferior, medial and lateral) using connecting dots
D71	Consider mark planned muscle release (dual plane) and new IMF and incision

Draping and Positioning (N = 9 items)

D72	Consider positioning patient securely in a supine position with both arms to side and limbs secured
A61	Awareness of the need to put patients in semi-sitting position for better visualization of results and the need to secure the patient's limbs to avoid falls and limb mobility
A62	Awareness of malposition or hyperextension of limbs and effect on symmetry and accuracy of results intra-operatively and postoperative recovery
D73	Consider confirming the position of arms by checking alignment of clavicles to avoid inaccuracy
D74	Consider operative timeout to check patient's name, identification, site and nature of procedure crosscheck with consent, anesthesia, antibiotic administration, equipment and implant availability
D75	Consider prepping clavicle to umbilicus and draping patient under a completely aseptic technique
D76	Consider the use of preoperative antibiotics to reduce the bacterial load and prevent pocket, skin, and implant contamination, infection and further complications
D77	Consider placing nipple shields underneath and on the nipple to avoid contamination
D78	Consider infiltration with epinephrine and bupivacaine (incision and pocket) to ↓bleeding and pain

IMF Incision and Dissection to Deep Fascia (N = 4 items)

D79	Consider incising using a scalpel based on pre-operative marks and dissect to Scarpa's fascia
D80	Consider lifting superior flap with non-dominant hand to identify the correct fascial plane
A63	Awareness of the correct plane at the Scarpa's fascia to avoid inadvertent deep plane dissection
D81	Consider dissecting superiorly + forward to form a sling of fascia to transpose during the closure

Appendix 3. Summary of 32 items for sub-sections within peri-operative preparation synthesized after 5 rounds of data analysis for the success of breast augmentation.

A (Situation awareness); D (Decision-making); NAC (Nipple areola complex); IMD (Intermammary distance); UpP (upper pole); LoP (lower pole); H (height); BW (base width); IMF (inframammary fold); N-S (Nipple-Sternal)

Pocket Dissection and Design

Subglandular Pocket Dissection (N = 5 items)	
A64	Awareness of plane between mammary gland (yellow) and Pectoralis major muscle (red) as the pectoralis fascia to avoid inadvertent deep plane dissection and excessive tissue trauma
D82	Consider dissecting into the plane of pectoralis fascia (glistening fascia) - superficial to the pectoralis major
A65	Awareness of boundaries of dissection based on pre-operative marks to avoid over dissection
A66	Awareness of the principles of dissection and prospective hemostasis to avoid bleeding
A67	Awareness of inadvertent deep dissection and correction of dissection plane - no need to repair the false plane
Subpectoral Pocket Dissection (N = 14)	
A68	Awareness of the yellow triangle as the fat plane between serratus and pectoral or by following the pectoralis major muscle border laterally to identify the correct plan of dissection into the pectoral pocket
A69	Awareness of loose areolar tissue of pectoral muscle between pectoralis major muscle and intercostal muscles and ribs to avoid deep dissection and pneumothorax
A70	Awareness of accuracy of boundaries of dissection on pre-operative marks to avoid over dissection
A71	Awareness of the principles of dissection and prospective hemostasis to avoid bleeding
A72	Awareness of the risk of bleeding in the superior medial pocket, medial perforators and inferior-medial to the NAC
D83	Consider dissection of pectoral pocket and muscle attachment release based on pre-operative marks
D84	Consider dissection of the inferior pole with radial scoring in cases of lower pole constriction (Tuberous)
A73	Awareness of fibrous muscle insertions in cases of tuberous breast and medial insertions to avoid inadvertent tissue injury and pneumothorax
D85	Consider preserving medial pectoralis major attachments to avoid symmastia, bleeding, and excess trauma
D86	Consider thinning out pectoralis muscle to reduce risk of lateral auto-dissection and ↓IMD (cleavage)
D87	Consider guiding pocket dissection by probing with fingers to check mismatch to markings on the skin
A74	Awareness to need to plicate and correct for over dissection of pocket to avoid malposition
D88	Consider avoiding sharp dissection beyond the lateral edge of nipple (2cm medial to planned implant BW)
A75	Awareness of sensory innervation (lateral branches of 4th and 5th ICN) to avoid extreme lateral dissection
Managing Intraoperative Errors (N = 9 items)	
D89	Consider communicating issues such as chest wall injuries or uncontrollable bleeding to team members (especially anesthesia) to allow for a team effort to managing the issue
A76	Awareness to the presence of deep dissection and occurrence of pneumothorax and the patient stability to avoid respiratory compromise intraoperatively
D90	Consider managing small chest wall injuries by inserting a Foley or a pigtail catheter and a purse-string suture around it and tying the purse following high-pressure positive ventilation
D91	Consider repair of larger chest wall injuries by inserting a chest tube connected to an underwater seal and supporting repair with surrounding tissue
D92	Consider wrapping up the procedure and transfer to higher levels of care in severe compromise once stable
D93	Consider monitoring compromised patients for 24 hours post-operatively and obtain an upright chest x-ray to check for resolving
D94	IF bleeding was noted, consider increasing the field of view by gentle retraction and dry the field to identify the source and attempt to control the bleeding using electrosurgical devices
D95	IF bleeding was uncontrollable consider application direct pressure without abrading tissue OR pack the current pocket and wait for bleeding to stop
A77	Awareness of the risk of pneumothorax, excessive tissue injury, and further bleeding with panic or erroneous use of electrosurgical devices

Appendix 4. Summary of 28 items for sub-sections within pocket dissection and design, synthesized after 5 rounds of data analysis for the success of breast augmentation.

A (Situation awareness); D (Decision-making); NAC (Nipple areola complex); IMD (Intermammary distance); H (height); BW (base width); IMF (inframammary fold); N-S (Nipple-Sternal); ICN (intercostal nerve)

Implant Handling and Insertion

Pocket Preparation (N = 4 items)	
D96	Consider irrigating pocket prior to implant insertion using an antibiotic solution to prevent infection
A78	Awareness of complete the sterility, secured hemostasis and dryness of the pocket prior to implant insertion
D97	Consider the triple antibiotic solution (Bacitracin, Gentamicin, Ancef) with iodine supported by evidence
D98	Consider single antibiotic solution (Bacitracin) with iodine as an antibiotic solution to reduce infections and reduce particulates in pocket (no evidence linking to reducing CC)
Implant Preparation and Handling (N = 6 items)	
D99	Consider using double gloves and/or change gloves after dissection of pocket to reduce bacterial load
D100	Consider washing gloves with iodine solution 6-8 times after dissection of pocket to reduce bacterial load
D101	Consider avoiding implant handling until insertion to avoid implant contamination
D102	Consider dipping implant and all used instruments in antibiotic solution to reduce bacterial load in pocket
D103	Consider a minimal implant touch technique and limiting handling to a single person (1st surgeon) to reduce contamination risk and implant loss
D104	Consider re-prepping / re-sterilizing the field (incision site) and putting nipple shields on the incision to avoid implant skin contact and reduce implant and pocket contamination
Implant Insertion and Pocket Adjustments (N = 13 items)	
D105	Consider inserting the implant through wound while avoiding skin contact to reduce implant contamination
A79	Awareness of implant orientation (right side up, and correct rotation) in shaped and full height textured implants to avoid mal position of implant and bad aesthetic outcomes
D106	Consider the use of sleeves/funnels for large implants or smaller incisions to facilitate implant insertion
D107	Consider avoiding the use of sleeves or funnels to prevent tissue injury and implant rupture
D108	Consider inspection while in semi-sitting position to compare symmetry of pocket dissection
D109	Consider adjustment of IMF fold and pocket dimensions after implant insertion to ensure symmetry
D110	Consider inspection of pre-operative standing photographs to allow adjustments based on upright image
A80	Awareness of breast tightness, malposition in any axis, asymmetry of pocket, IMF, and NAC location to allow for accurate and symmetrical adjustments
D111	Consider plication of the pocket in cases of over dissection and dissect further in cases of under dissection to adjust dissected pocket to obtain accurate and symmetrical results
D112	Consider minor adjustments while the implant is in place OR taking implant out for major adjustments
D113	Consider placing a sling of an acellular dermal matrix (AlloDerm) after readjust IMF to support new IMF
A81	Awareness of preference to make decisions intra-operatively that meet expectations
D114	Consider using smaller implants if the pocket is too tight for the implant to avoid compromising pocket

Appendix 5. Summary of 23 items for sub-sections within implant handling and insertion, synthesized after 5 rounds of data analysis for the safety of breast augmentation.

A (Situation awareness); D (Decision-making); IMF (inframammary fold); N-S (Nipple-Sternal); CC (capsular contracture); NAC (Nipple areola complex);

Pocket and Skin Closure and Postoperative Care

Pexy of Fascia and Closure (N = 9 items)	
D115	Consider pexying fascia from upper flap to rib fascia (lower) to support dropped fold to cooper's ligaments
D116	Consider using a sling created on the incision to pexy the fascia and support dropped IMF
D117	Consider using heavy (2-0) absorbable or non-absorbable sutures to pexy fascia in order to support IMF
A82	Awareness of hemostasis within the incision to avoid postoperative bleeding and hematoma
A83	Awareness of the need for three-layer closure (Scarpa's, subdermal and subcuticular) to obtain a tight seal
D118	Consider closure of fascia using 3 interrupted distant sutures done under direct vision to avoid implant injury and tied after sutures are in place to allow for the adequate field of view
A84	Awareness + direct visualization of implant, needle and driver axis during closure to avoid implant injury
D119	Consider assistance in terms of further retraction for the improved view of the implant, use of blunt malleable retractors to protect the implant, or driving needle away from implant to prevent implant injury and loss
A85	Awareness to fat strangling during closure to avoid fat necrosis and further tissue trauma and inflammation
Dressing and Post-operative Plan (N = 4 items)	
D120	Consider using standard dressing and use special dressings and bra support only as indicated in adjunct procedures to support IMF and reduce fluid collection
D121	Consider adequate pain control and recommend gentle mobility and exercise as tolerable to allow for a smooth recovery and early return to work and prevent litigations
D122	Consider adequate and early follow-up to view results and assess recovery and to address further concerns
D123	Consider satisfaction documentation pre and postoperatively using Breast-Q questionnaire to allow for self-monitoring of results and research and outcome-oriented practice

Appendix 6. Summary of 13 items for sub-sections of pocket and skin closure and postoperative care, synthesized after 5 rounds of data analysis for the success of breast augmentation.
A (Situation awareness); D (Decision-making); IMF (inframammary fold);

	Pitfall / Cause	Risk	Prevention	Management
Pre-operative Issues	**1) Patients with unrealistic expectations**			
	Requesting unrealistic or disproportionate volume objectives	Multiple consultations, history of cosmetic surgeries and media influence	Appropriate patient education and promotion of realistic objectives	Re-educate on risks for complications and future aesthetics, consider denial
	Requesting unrealistic incision size	Risk for implant injury/rupture, and skin edges trauma		Explain benefits of proper size selection
	Extremely narrow IMD (cleavage) <3-4cms	Risk for symmastia, visibility, palpability, traction rippling		Explain risks and need to preserve medial origins
Peri-operative Issues	**2) Patient / limb fall / injury**			
	Not securing the patient in position	Lack of awareness and inappropriate positioning	Awareness to secure the patient in semi-sitting position	Secure patients in position with both arms and LL secured to sides
	Fall of limb	Lack of awareness and inappropriate/loose securing	Communication during mobilization and arms stabilization	Reposition the limb and stabilize limb to table
	Hyper abduction injury and postoperative pain	Need for further space with multiple operators	Secure arms in neutral abduction and use of space beyond arms	Reposition and secure arms

Appendix 7. Summary of 2 issues with pre- and peri-operative care, synthesized after 5 rounds of data analysis. Root pitfalls, risks, preventative measures and management were identified.

IMD (Intermammary distance); LL (lower limbs)

Intra-operative Issues

Pitfall / Cause	Risk	Prevention	Management
3) Pneumothorax			
Going through chest wall deep to pectoralis minor	Inadequate awareness of plane of dissection in upper pocket	Avoid dissection below pectoralis minor by medial to lateral dissection in Upper pole	Communicate with anesthesia (team), call for help and check patient stability (Vitals)
Elevating serratus while lifting Subpectoral pocket	Inadequate awareness of plane of dissection in the lower pocket	Careful dissection inferiorly by lifting muscle fibres and noting tenting of pectoralis	If small - insert a Foley or a pigtail catheter and close a purse-string tightly around it after Valsalva
Fibrous insertions at tapering zone (2 cm above IMF)	Tuberous breast, inferior muscle attachment (strong)	Awareness of fibrous insertions during muscle dissection on the ribs	If large or respiratory compromise - chest tube and connect to an underwater seal
Injury to chest wall while attempting to control bleeding	Aggressive attempt to control bleeding	prospective hemostasis and appropriate coagulating of vessels with energy devices	Confirm resolution with X-ray afterwards - monitor for 24 hours
4) Uncontrollable bleeding			
Extreme dissection in vascular areas	High medial superior bleeding, medial sternal attachment and	Limit superior dissection, stop at medial perforators (1.5 cm from sternum)	Communicate with anesthesia (team) about bleeding and check vitals, call for help
Inadequate or improper control of bleeding	Erroneous use of energy devices and gauze abrading	Effective use of energy devices and cauterization	Apply compression, dry field and attempt to control bleed
Vessel withdrawal and bleeding after inadvertent vessel injury	Lack of awareness of anatomy of breast perforators	Awareness of IM vessels and large perforators inferior medial to NAC	Packing of pocket and wait of bleeding to stop or apply ties (figure of eight)
Perforator injury	Use of subfacial plane	Cauterize visible perforators	
Lack of awareness of prospective hemostasis (vessel anticipation)	Dissection of medial sternal pectoral insertions or deep medial dissection	Avoid abrading with gauze sponges	
Limited visibility of pocket during dissection	Use of incisions other than IMF	IMF incision, special equipment for visibility	Increase visibility by better retraction
5) Deep dissection / false plane			
Deeper to Scarpa's Fascia while creating incision	Lack of awareness of planes and delineation of tissue	Lift superior flap with non-dominant hand	Identify and correct any pocket over-dissection
Deeper to pectoralis fascia in a SG plane into a false plane / SP plane	Lack of awareness of pectoralis plane and inadequate exposure	Awareness of plane of mammary gland and pectoralis major fascia	Don't repair the muscle defect, leave it alone
Deeper to Subpectoral plane of loose tissue	Dissection of medial, upper lateral, or lower lateral pockets	Identify fat plane between serratus and pectoralis	
Deep dissection during pocket creation	Rushed and traumatic dissection	Awareness of plane -measure twice, cut once	
Inadequate exposure of plane of dissection	Lack of assistance and use of traditional retractors	Use of special retractors (lighted +/- vacuum)	

Appendix 8. Summary of 3 issues with Intra-operative care, synthesized after 5 rounds of data analysis. Root pitfalls, risks, preventative measures and management were identified.

IMF (inframammary fold); IMD (Intermammary distance); NAC (Nipple areola complex); SP (sub-pectoral); UP (upper pole);

Implant Insertion and Handling Issues

Pitfall / Cause	Risk	Prevention	Management
6) Infection (Pocket / implant)			
Implant contamination	Direct skin contact, use of same gloves, and pocket contamination	Minimal touch of the implant to a single person, change gloves and dip in antibiotic solution	
Pocket contamination	Aggressive dissection	Use triple antibiotic solution and 10-day antibiotic course	
Skin flora contact	Inappropriate prepping, draping breach, or skin at incision	Sterile technique, shielding skin, and re-prepping	
7) Insertion difficulty			
The implant doesn't fit through the incision	Small IMF incision and large volume implants	Proper planning of incision size based on implant	Increase size of incision laterally
8) Issues of implant availability			
Not ordering/missing implant	Lack of appropriate communication	Effective communication and planning pre-operatively	Cancel procedure, explain to the patient and reschedule
Following implant loss/injury	Lack of awareness to need for backup implant	Ordering of implants (Size +/- *3), sizers	
9) Implant loss			
Carelessness / inappropriate implant handling	Handling by multiple operators, early unpacking of implant and rush in procedure	Avoid opening implant until time of insertion and limit handling to single operator	Use available backup implant
10) Implant/skin injury during the closure			
The pressure of implant during insertion	Small IMF incision and large volume implants	Adequate incisions with limited use of large implants	Use available backup implant
Instrumental injury to skin	Use of funnels/sleeves and bad instruments	Check instruments and energy devices position	
Use of sharps near implant	Lack of blunt protection to implant	Blunt protection and proper isolation of flap	
Inadequate visualization of implant	Smaller IMF incisions and lack of assistance	Good retraction and preserve visualization before tying	
11) Mal position			
Insertion of implants in wrong orientation	Use of shaped (anatomical) and H>BW implants (full height)	BW shouldn't be > implant height and awareness of orientation at insertion	Adjust orientation if noted intraoperatively, or withdraw and reinsert implant
Rotation of implant during insertion	Use of sleeves/funnels or twisting in tight incisions	Adequate incision size, check implant orientation	
Rotation inside the pocket	Loosely fitting pocket and smooth implants	Use of textured implants and creating a well fit pocket	
12) Tight pocket / closure			
Under dissected tight pocket	Use of large implants	Adherence and respect to pocket marks	Further pocket dissection (adjust while inside if minor)
Firm parenchyma (concentrated centrally)	Tuberous breast	Awareness of parenchymal size (BW) and elasticity	Score parenchyma to splay it out

	Implant volume larger than pocket	Patients with unrealistic expectations in terms of size of implant	Appropriate pre-operative planning and addressing of unrealistic expectations	Choose smaller implant but stick to patient expectations and consented co-decisions
	Pitfall / Cause	**Risk**	**Prevention**	**Management**
Implant Insertion and Handling Issues	**13) Caudal malposition / asymmetry**			
	Over dissection of muscle (high / caudally)	Medial Subpectoral pocket	Limited and precise muscle dissection, marking cephalic boundaries on cautery	
	14) Bottoming out			
	Malposition of the implant (inferior/superior) in relation to IMF / breast	Tight / Constricted lower pole (Tuberous breast)	Lowering and pexying of IMF to secure implant	Incise superiorly and forward to maintain a sling of fascia for pexying and adjust IMF
	Designing/marking / dissecting a loose pocket	Marking larger pockets and no adjustment on semi-sitting position	Respect breast boundaries and accuracy in the design of pocket, IMF and incision	Intra-op- adjust IMF and pexy over-dissected IMF (lower) and place a sling of Alloderm
	Inferior displacement of the implant by auto-dissection (muscle)	Subpectoral pocket without the use of dual plane / adequate muscle release in muscular patients	Forward planning - prospective mindset during dissection to release muscle	Post-op- perform capsule-rhaphy (inferior)
	15) Medial Malposition - Narrow IMD - Symmastia			
	Extreme medial dissection of pocket	Patients with narrow chest / IMD	Respect to medial border (IMD > 3cm)	
	Extreme medial sternal insertion release	Lack of awareness of boundaries of dissection	Awareness of pre-operative marks of dissection border	
	16) Lateral malposition - Wide IMD			
	Implant mobilization	Use of smooth implants	Use of textured implants	Intra-op- take the implant out, and pexy over dissected pocket
	Pectoral animation leading to lateralization of the implant	Use of Subpectoral pocket	Subglandular pocket in muscular patients or thin-out of sternal attachments	Post-op- perform capsule-rhaphy (Lateral)
	Inaccurate pocket dissection, marking or design	Patients with wide IMD / chest wall	Awareness of lateral border- Anterior axillary line, limit to <2cm of planned pocket	
	Under dissection / release of muscle	Muscular patients / tight Subpectoral pocket	Forward planning and appropriate muscle release	

Appendix 9. Summary of 11 issues associated with implant insertion and handling, synthesized after the five rounds of inductive data analysis. For each issue, root pitfalls and causes, risks, preventative measures and management strategy were identified.

IMF (inframammary fold); IMD (Intermammary distance); NAC (Nipple areola complex); SP (sub-pectoral);

Post-operative Issues

Pitfall / Cause	Risk	Prevention	Management
17) Capsular Contracture - an inherited biological occurrence			
Bleeding in pocket	Aggressive dissection	Bloodless dissection	Complete capsulectomy
Infection/contamination of pocket or implant	Use of silicone / textured implants	Use of antibiotic solutions, and shielding skin (NAC)	Convert SG to SP following capsulectomy
Tissue trauma and inflammation	Erroneous aggressive pocket dissection	Meticulous dissection, avoid tissue trauma	
Sharp / blunt dissection	History of radiation therapy to the chest	Use of energy devices at lowest effective current	
Innate factors	Subglandular pocket, smoking, pregnancy	Use of Subpectoral pocket	Dependent – Capsulotomy / capsulorrhaphy
18) Visibility, palpability, rippling			
Thin muscle	Thin, non-muscular, young	Detect muscle bulk (feeling axilla)	
Implant properties	Saline, round, low profile / undefiled implants	Avoid Saline implants in thin patients	
Thin tissue envelope	Thin tissue STPT <2cm (UpP) / <1cm at any location	Use of BW =/< current BW to allow adequate tissue coverage	
Thin pocket	Use of Subglandular pocket	Use of Subpectoral pocket	
19) Implant Extrusion			
High pocket pressure and muscle pressure	Thin envelop, small pocket, inadequate IMF closure	Adequate watertight closure and well fit pocket design	
20) Asymmetrical results			
Lack of awareness of asymmetry of breast	Augmentation exaggerates asymmetry	Comparison of breast volume on both sides	Use of anatomical implants to address 5mm IMF asymmetry
Lack of awareness of spine deformity scoliosis (vertical)	Breast / NAC asymmetry	If Asymmetry exists - plan repair/adjunct procedures	Compare to pre-operative standing photographs and NAC relation to IMF
Non-objective basis of decision making	Inaccuracy of preoperative skin markings	Intra-operative revision and adjusting of pocket (semi-sitting)	Revise pocket as needed - plicate when over dissected
Asymmetry/patient mal position during pocket adjustment	Inadequate patient stabilization / inappropriate patient positioning	Adequate patient stabilization and symmetrical position (clavicles at level)	Adjust pocket dimensions and IMF on pre-operative markings to achieve symmetry
Lack of awareness of asymmetry of breast intra-operatively	Asymmetrical patient positioning or hyper-abduction of upper limbs	Visual inspection for symmetry on the semi-sitting position after making sure patient is centrally positioned	
Inaccurate pocket dissection/design	Inaccuracy of preoperative skin markings	Accurate preoperative marking for symmetry	
21) Tuberous breast			
Lack of awareness of tubal breast / lower pole deformation	Use BW < current BW if <10cm (tuberous / lower pole constriction)	Address lower pole constriction and release fibrosis with radial scoring	
22) Chest wall deformity			

	Lack of awareness of rounded thorax (deformity)		Awareness of the need for adjuncts and special implants in Poland syndrome and Pectus Excavatum	

	Pitfall / Cause	Risk	Prevention	Management
Post-operative Issues	**23) Ptosis**			
	Postpartum tissue atrophy and poor skin elasticity	Lack of awareness to skin quality, and envelope compliance (APSS>3cm)	More muscle release / dual plane / use of full projection implants	
	Lack of awareness of preoperative ptosis	Pregnancy, lactation, old age	Use of round implants to avoid extenuating lower pole fullness	
	Upper pole collapse (when upright)	Lack of awareness of upright orientations (semi-sitting), use of non-form stable implants	Use of form stable implants to maintain upper pole fullness	
	24) Parenchymal atrophy and disruption			
	Excessive pressure from the implant in a tight pocket	Use of high projection or high-volume implants	Avoid the use of large volume implants (>350-400cc) and focus on BW	
	Lack of skin envelop compliance (APSS<3cm)	Thin, young, and athletic patients	Use of moderate projection implants if APSS<3cm	
	Incision into the parenchyma	Use of incisions other than IMF	Use of IMF incision	
	25) Hematoma			
	Lack of awareness to concealed bleeding	Use of incisions other than IMF	Awareness of perforator during dissection with adequate exposure	
			Bloodless dissection - zero tolerance for minimal bleeds	
			Infiltration with epinephrine (incision and pocket)	
	26) Leaking			
	Spontaneous leaks	Saline implants	Perform a leak test on inflatable implants before insertion	
	Silent leaks and implant injury at insertion	Silicone implants	Avoid implant injury and replace when in doubt	
	27) Patient dissatisfaction with the results despite met expectations			
	Lack of identification of patients' objectives	Patients with unrealistic expectations	Appropriate understanding and identification of problem	
	Lack of identification of psychological instability	Psychological instability	Explain limitations of surgery to correct asymmetry	
	Depending on volume solely in implant choice	Having had multiple other cosmetic procedures	Avoid use of huge implants (>350-400cc) and focus on BW	
	Lack of appreciation of body habitus and chest proportions	Tall patients, patients with wide hips, and patients with body ratio idiosyncrasy	Higher profile for wider hips, thin envelop, petite habitus. Medium height implants for tall, wide IMD	
	Un-natural look (Breast proportions of UP:LP)	Use of saline implants and lack of respect to breast proportions	Use of anatomical implants, adjusting implant height on height or SN and breast proportions	Lower IMF to adjust UP:LP fullness

	Pitfall / Cause	Risk	Prevention	Management
	Distortion of NAC relative position	Designing pocket with current NAC position	Design pocket around NAC position with maximal stretch	
	Visible / hypertrophied scars	Improper incision and lack of awareness to innate factors	Lower IMF and place IMF incision blow new IMF as it rises postop	
Post-operative Issues	**28) Need for reoperation (Non-complicated)**			
	Depending on implant volume in decision making and planning	Focus on patient expectations and overall volume in decision making	Focus on BW leads to less size related reoperation rates	
	Leaking, and spontaneous deflation	Use of saline implants	Avoid implant injury and replace when in doubt	
	29) Delayed wound healing			
	Patient-related factors	Smoking, diabetes, and radiation exposure	Delay the procedure if the patient is a smoker	
	Tissue trauma and inflammation	Erroneous traumatic incision using energy devices	Incision using scalpel based on pre-operative marks	
	Closure under tension	Tight incision closure, tight pocket design and large implant volume	Appropriate closure of pocket and avoiding large implants	
	30) Pain / sensory loss			
	Aggressive dissection	Use of sub-pectoral pocket	Meticulous dissection of pocket	Conservative management
	Inadequate pain control	Lack of prospective pain control planning	Infiltration with Marcaine (incision and pocket)	
	Inadequate postoperative pain control	Early return to work/activity	Educate on limited postoperative activity and adequate pain control and coverage	Supplement with further pain control and limit activity
	Aggressive pocket dissection lateral to NAC	Inframammary and Peri-areolar incisions	Awareness of branches of 4th and 5th ICN) - limited lateral dissection at NAC / beyond pectoralis Major	
	31) Seroma			
	Excessive tissue trauma/dissection	Erroneous aggressive pocket dissection	Meticulous dissection of pocket	Conservative management
	Presence of double capsule (intermediate sheering force)	Early return to work/activity	Limited return to activity and good control of postoperative pain	If late / failed - put catheter to drain and send for cytology (? ALCL)

Appendix 10. Summary of 25 post-operative issues, synthesized after the five rounds of inductive data analysis. For each issue, root pitfalls and causes, risks, preventative measures and management strategy were identified.

IMF (inframammary fold); IMD (Intermammary distance); NAC (Nipple areola complex); SP (sub-pectoral);

16. References

1. Knox, A.D., et al., *Competency-based medical education for plastic surgery: where do we begin?* Plast Reconstr Surg, 2014. **133**(5): p. 702e-710e.
2. Iobst, W.F., et al., *Competency-based medical education in postgraduate medical education.* Med Teach, 2010. **32**(8): p. 651-6.
3. Khan, M.S., et al., *Assessing surgical skill using bench station models.* Plast Reconstr Surg, 2007. **120**(3): p. 793-800.
4. Pugh, C., et al., *Outcome measures for surgical simulators: is the focus on technical skills the best approach?* Surgery, 2010. **147**(5): p. 646-54.
5. Sadideen, H., et al., *Proposing "the burns suite" as a novel simulation tool for advancing the delivery of burns education.* J Burn Care Res, 2014. **35**(1): p. 62-71.
6. Cook, D.A. and M.M. Triola, *Virtual patients: a critical literature review and proposed next steps.* Med Educ, 2009. **43**(4): p. 303-11.
7. Stern, C., et al., *Integration of surgical simulation in plastic surgery residency training.* Stud Health Technol Inform, 2012. **173**: p. 497-9.
8. Wingfield, L.R., et al., *Cognitive Task Analysis: Bringing Olympic Athlete Style Training to Surgical Education.* Surg Innov, 2014.
9. Andersen, D.K., *How can educators use simulation applications to teach and assess surgical judgment?* Acad Med, 2012. **87**(7): p. 934-41.
10. Hall, J.C., C. Ellis, and J. Hamdorf, *Surgeons and cognitive processes.* Br J Surg, 2003. **90**(1): p. 10-6.
11. Courteau, B.C., et al., *The Development of Assessment Tools for Plastic Surgery Competencies.* Aesthet Surg J, 2015. **35**(5): p. 611-7.
12. Frank, J.R., et al., *Toward a definition of competency-based education in medicine: a systematic review of published definitions.* Med Teach, 2010. **32**(8): p. 631-7.
13. Bandiera, G., M.K. Hynes, and S.M. Spadafora, *Duty hour restrictions: organizational dynamics, systems issues, and the impact on faculty.* BMC Med Educ, 2014. **14 Suppl 1**: p. S5.
14. Bhatti, N.I. and C.W. Cummings, *Competency in surgical residency training: defining and raising the bar.* Acad Med, 2007. **82**(6): p. 569-73.
15. Schenker, M., et al., *Aesthetic surgical training in the UK independent sector--the clients' view: Results of a survey on 155 private patients.* J Plast Reconstr Aesthet Surg, 2006. **59**(11): p. 1188-92.
16. Kasten, S.J., et al., *Toward outcomes-based plastic surgery training: a needs assessment of recent graduates.* Plast Reconstr Surg, 2009. **124**(5): p. 1703-10.
17. Bancroft, G.N., et al., *Outcome-based residency education: teaching and evaluating the core competencies in plastic surgery.* Plast Reconstr Surg, 2008. **121**(6): p. 441e-448e.
18. Luker, K.R., et al., *The use of a cognitive task analysis-based multimedia program to teach surgical decision making in flexor tendon repair.* Am J Surg, 2008. **195**(1): p. 11-5.
19. Pyle, J.W., et al., *Outcomes analysis of a resident cosmetic clinic: safety and feasibility after 7 years.* Ann Plast Surg, 2010. **64**(3): p. 270-4.
20. Frank, J.R. and B. Langer, *Collaboration, communication, management, and advocacy: teaching surgeons new skills through the CanMEDS Project.* World J Surg, 2003. **27**(8): p. 972-8; discussion 978.

21. Frank JR, S.L., Sherbino J, editors, *Draft CanMEDS 2015 Physician Competency Framework – Series III.* . 2014, The Royal College of Physicians and Surgeons of Canada.
22. McGrath, M.H., *The plastic surgery milestone project.* J Grad Med Educ, 2014. **6**(1 Suppl 1): p. 222-4.
23. Tyler, R., *Basic principles of curriculum and instruction.* 1949, Chicago: University of Chicago Press.
24. Frank, J.R., et al., *Competency-based medical education: theory to practice.* Med Teach, 2010. **32**(8): p. 638-45.
25. Education, A.C.f.G.M., *Outcome project*. 2001, ACGME: Chicago, IL.
26. Swing, S.R. and C.C. International, *Perspectives on competency-based medical education from the learning sciences.* Med Teach, 2010. **32**(8): p. 663-8.
27. Ten Cate, O., *Nuts and bolts of entrustable professional activities.* J Grad Med Educ, 2013. **5**(1): p. 157-8.
28. Jones, M.D., Jr., et al., *Perspective: Competencies, outcomes, and controversy--linking professional activities to competencies to improve resident education and practice.* Acad Med, 2011. **86**(2): p. 161-5.
29. Frank, J.R., *Canadian urology programs can be leaders in competency-based education.* Can Urol Assoc J, 2008. **2**(4): p. 405-6.
30. Taber, S., et al., *Identifying the policy implications of competency-based education.* Med Teach, 2010. **32**(8): p. 687-91.
31. Nguyen, V.T. and J.E. Losee, *Time- versus Competency-Based Residency Training.* Plast Reconstr Surg, 2016. **138**(2): p. 527-31.
32. Silvestre, J., et al., *Variable Operative Experience in Hand Surgery for Plastic Surgery Residents.* J Surg Educ, 2017. **74**(4): p. 650-655.
33. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* J Clin Epidemiol, 2009. **62**(10): p. 1006-12.
34. Bloom, B.S.E.E., M.D., Furst, E.J., Hill, W.H., Krathwohl, D.R. , *Taxonomy of Educational Objectives, Handbook I: The Cognitive Domain*. 1956, New York: David McKay Co Inc.
35. Kirkpatrick, *50 years of evaluation, Training and development*. 2010, American society for training and development.
36. Simpson, J.S. and A.S. Scheer, *A Review of the Effectiveness of Breast Surgical Oncology Fellowship Programs Utilizing Kirkpatrick's Evaluation Model.* J Cancer Educ, 2015.
37. Beckman, T.J., D.A. Cook, and J.N. Mandrekar, *What is the validity evidence for assessments of clinical teaching?* J Gen Intern Med, 2005. **20**(12): p. 1159-64.
38. Reed, D.A., et al., *Association between funding and quality of published medical education research.* JAMA, 2007. **298**(9): p. 1002-9.
39. Reed, D.A., et al., *Predictive validity evidence for medical education research study quality instrument scores: quality of submissions to JGIM's Medical Education Special Issue.* J Gen Intern Med, 2008. **23**(7): p. 903-7.
40. Dai, J.C., T.S. Lendvay, and M.D. Sorensen, *Crowdsourcing in Surgical Skills Acquisition: A Developing Technology in Surgical Education.* J Grad Med Educ, 2017. **9**(6): p. 697-705.

41. Ribeiro, I.B., et al., *Simulation-Based Skill Training for Trainees in Cardiac Surgery: A Systematic Review.* Ann Thorac Surg, 2017.
42. Smith, R.P. and L.A. Learman, *A Plea for MERSQI: The Medical Education Research Study Quality Instrument.* Obstet Gynecol, 2017. **130**(4): p. 686-690.
43. Muzyk, A.J., et al., *Substance use education in US schools of pharmacy: A systematic review of the literature.* Subst Abus, 2017. **38**(4): p. 455-463.
44. Pfandler, M., et al., *Virtual reality-based simulators for spine surgery: a systematic review.* Spine J, 2017. **17**(9): p. 1352-1363.
45. Timberlake, M.D., et al., *What Do We Know About Intraoperative Teaching?: A Systematic Review.* Ann Surg, 2017. **266**(2): p. 251-259.
46. Bills, C.B. and J. Ahn, *Global Health and Graduate Medical Education: A Systematic Review of the Literature.* J Grad Med Educ, 2016. **8**(5): p. 685-691.
47. Cook, D.A. and D.A. Reed, *Appraising the quality of medical education research methods: the Medical Education Research Study Quality Instrument and the Newcastle-Ottawa Scale-Education.* Acad Med, 2015. **90**(8): p. 1067-76.
48. Knox, A.D.C., et al., *Consensus of Leaders in Plastic Surgery: Identifying Procedural Competencies for Canadian Plastic Surgery Residency Training Using a Modified Delphi Technique.* Plast Reconstr Surg, 2018. **141**(3): p. 417e-429e.
49. Battles, J.B., *Improving patient safety by instructional systems design.* Qual Saf Health Care, 2006. **15 Suppl 1**: p. i25-9.
50. Shih, J.G., et al., *Burn Care and Surgical Exposure amongst Canadian Plastic Surgery Residents: Recommendations for Transitioning to a Competency-Based Medical Education Model.* J Burn Care Res, 2019. **40**(6): p. 796-804.
51. Silvestre, J., et al., *A Comparison of Case Volume in Craniofacial Surgery by Plastic Surgery Residency Training Model.* Ann Plast Surg, 2020. **84**(4): p. 449-454.
52. Zevin, B., et al., *A consensus-based framework for design, validation, and implementation of simulation-based training curricula in surgery.* J Am Coll Surg, 2012. **215**(4): p. 580-586 e3.
53. Sue, G.R., W.C. Covington, and J. Chang, *The ReSurge Global Training Program: A Model for Surgical Training and Capacity Building in Global Reconstructive Surgery.* Ann Plast Surg, 2018. **81**(3): p. 250-256.
54. Sillah, N.M., et al., *The New Accreditation Council for Graduate Medical Education Next Accreditation System Milestones Evaluation System: What Is Expected and How Are Plastic Surgery Residency Programs Preparing?* Plast Reconstr Surg, 2015. **136**(1): p. 181-7.
55. Ganesh Kumar, N., J. Marwaha, and B.C. Drolet, *Milestones on the Plastic Surgery In-Service Training Examination.* J Surg Educ, 2019. **76**(5): p. 1370-1375.
56. Sadideen, H., et al., *How Educational Theory Can Inform the Training and Practice of Plastic Surgeons.* Plast Reconstr Surg Glob Open, 2018. **6**(12): p. e2042.
57. Chow, I., et al., *Milestones in Plastic Surgery: Attending Assessment versus Resident Assessment.* Plast Reconstr Surg, 2019. **143**(2): p. 425e-432e.
58. Kitzmiller, W.J., *Evidence-Based Education in Plastic Surgery.* Plast Reconstr Surg, 2016. **137**(3): p. 648e-649e.
59. Wright, T.C., et al., *A cost-effective training tool for flexor tendon repair: pig's trotters.* J Plast Reconstr Aesthet Surg, 2006. **59**(1): p. 107-8.

60. Zetlitz, E., et al., *Objective assessment of surgical training in flexor tendon repair: The utility of a low-cost porcine model as demonstrated by a single-subject research design.* Journal of Surgical Education, 2012. **69**(4): p. 504-510.
61. Malic, C., S. Jivan, and S. Majumder, *A simple model for hand trauma training.* Journal of Hand Surgery: European Volume, 2007. **32**(5): p. 578-580.
62. Anwar, M., N. Renner, and M. Harris, *A simple teaching model for mucoperiosteal flaps and suturing techniques.* British dental journal, 1989. **166**(2): p. 38.
63. Berg, D., *A simple tool for teaching flap design with digital images.* Dermatologic Surgery, 2001. **27**(12): p. 1043-5.
64. Powell, A.R., et al., *Computer-Aided Design, 3-D-Printed Manufacturing, and Expert Validation of a High-fidelity Facial Flap Surgical Simulator.* JAMA Facial Plast Surg, 2019. **21**(4): p. 327-331.
65. Thomson, J.E., et al., *Current status of simulation training in plastic surgery residency programs: A review.* Arch Plast Surg, 2018. **45**(5): p. 395-402.
66. Kazan, R., et al., *The Montreal Augmentation Mammaplasty Operation (MAMO) Simulator: An Alternative Method to Train and Assess Competence in Breast Augmentation Procedures.* Aesthet Surg J, 2018. **38**(8): p. 835-849.
67. Zammit, D., et al., *Step-Specific Simulation: The Utility of 3D Printing for the Fabrication of a Low-Cost, Learning Needs-Based Rhinoplasty Simulator.* Aesthet Surg J, 2020.
68. Wright, W.K. and R.W. Kridel, *External septorhinoplasty: a tool for teaching and for improved results.* Laryngoscope, 1981. **91**(6): p. 945-51.
69. Porro, I., et al., *An integrated environment for plastic surgery support: building virtual patients, simulating interventions, and supporting intraoperative decisions.* Computerized Medical Imaging & Graphics, 2005. **29**(5): p. 385-94.
70. Oliker, A., et al., *Step-based cognitive virtual surgery simulation: an innovative approach to surgical education.* Studies in Health Technology & Informatics, 2012. **173**: p. 325-7.
71. Demirseren, M.E., et al., *Training of plastic surgery on the white board.* Plast Reconstr Surg, 2003. **111**(5): p. 1757-8.
72. Niamtu, J., 3rd, *The power of PowerPoint.* Plastic & Reconstructive Surgery, 2001. **108**(2): p. 466-84.
73. Oliker, A. and C. Cutting, *The Role of Computer Graphics in Cleft Lip and Palate Education.* Seminars in Plastic Surgery, 2005. **19**(4): p. 286-293.
74. Schendel, S., et al., *A surgical simulator for planning and performing repair of cleft lips.* Journal of Cranio-Maxillofacial Surgery, 2005. **33**(4): p. 223-228.
75. Nicolaou, M., et al., *An inexpensive 3-D model for teaching local flap design on the face and head.* Annals of the Royal College of Surgeons of England, 2006. **88**(3): p. 320.
76. Conde-Green, A., et al., *Weekly plastic surgery grand rounds: keeping up through social networking.* Plastic & Reconstructive Surgery, 2012. **130**(1): p. 239e-240e.
77. Glarner, C.E., et al., *Quantifying technical skills during open operations using video-based motion analysis.* Surgery, 2014. **156**(3): p. 729-34.
78. Gerstle, T., A.H. Hassanein, and E. Eriksson, *iPad integration in plastic surgical training: optimizing clinical efficiency, education, and compliance with the health insurance portability and accountability act.* Plastic & Reconstructive Surgery, 2015. **135**(1): p. 223e-5e.

79. Connolly, K.A., S.M. Azouz, and A.A. Smith, *Feedback in Plastic and Reconstructive Surgery Education: Past, Present, and Future.* J Craniofac Surg, 2015. **26**(8): p. 2261-3.
80. Papel, I.D. and R.I. Park, *Computer imaging for instruction in facial plastic surgery in a residency program.* Archives of Otolaryngology - Head and Neck Surgery, 1988. **114**(12): p. 1454-1460.
81. Moody, L., C. Baber, and T.N. Arvanitis, *Objective surgical performance evaluation based on haptic feedback.* Studies in Health Technology & Informatics, 2002. **85**: p. 304-10.
82. Berschback, J.C., et al., *Providing quantitative feedback when teaching tendon repair: A new tool.* Journal of Hand Surgery, 2005. **30**(6): p. 626-632.
83. Wanzel, K.R., et al., *Teaching technical skills: training on a simple, inexpensive, and portable model.* Plastic & Reconstructive Surgery, 2002. **109**(1): p. 258-63.
84. Davis, D. and G. Lee, *The use of standardized patients in the plastic surgery residency curriculum: teaching core competencies with objective structured clinical examinations.* Plast Reconstr Surg, 2011. **128**(1): p. 291-8.
85. Daniel, M., et al., *Clinical Reasoning Assessment Methods: A Scoping Review and Practical Guidance.* Acad Med, 2019. **94**(6): p. 902-912.
86. McKinnon, V.E., et al., *A Shift on the Horizon: A Systematic Review of Assessment Tools for Plastic Surgery Trainees.* Plast Reconstr Surg, 2018. **142**(2): p. 217e-231e.
87. Kohls-Gatzoulis, J.A., G. Regehr, and C. Hutchison, *Teaching cognitive skills improves learning in surgical skills courses: a blinded, prospective, randomized study.* Can J Surg, 2004. **47**(4): p. 277-83.
88. Kempton, S.J. and M.L. Bentz, *Making Master Surgeons Out of Trainees: Part I. Teaching Surgical Judgment.* Plast Reconstr Surg, 2016. **137**(5): p. 1646-53.
89. Tjiam, I.M., et al., *Designing simulator-based training: an approach integrating cognitive task analysis and four-component instructional design.* Med Teach, 2012. **34**(10): p. e698-707.
90. Chiniara, G., et al., *Simulation in healthcare: a taxonomy and a conceptual framework for instructional design and media selection.* Med Teach, 2013. **35**(8): p. e1380-95.
91. Maertens, H., et al., *Systematic review of e-learning for surgical training.* Br J Surg, 2016. **103**(11): p. 1428-37.
92. Jacovella, P.F., *Developing skills in rhinoplasty through cadaver training.* Aesthetic Surgery Journal, 2005. **25**(6): p. 643-5.
93. Murabit, A., et al., *Teaching ear reconstruction using an alloplastic carving model.* Journal of Craniofacial Surgery, 2010. **21**(6): p. 1719-21.
94. Wade, T.J. and T.P. Webb, *Tackling technical skills competency: A surgical skills rating tool.* Journal of Surgical Research, 2013. **181**(1): p. 1-5.
95. Flores, R.L., et al., *Measuring surgical competency in facial trauma: the Arch Bar Placement Assessment Scale.* Annals of Plastic Surgery, 2014. **73**(3): p. 299-303.
96. Nobis, C.P., et al., *Development of a haptic model for teaching in reconstructive surgery--the radial forearm flap.* Simulation in Healthcare: The Journal of The Society for Medical Simulation, 2014. **9**(3): p. 203-8.
97. Conway, J. and R. Gilder, *Videotaped and real-time color television in rhinoplasty training.* Canadian journal of otolaryngology, 1973. **Journal canadien d'otolaryngologie. 2**(3): p. 282-284.

98. Constantian, M.B., C. Ehrenpreis, and J.H. Sheen, *The expert teaching system: a new method for learning rhinoplasty using interactive computer graphics.* Plastic & Reconstructive Surgery, 1987. **79**(2): p. 278-83.
99. Tardy, M.E. and D. Broadway, *Graphic record-keeping in rhinoplasty: A valuable self-learning device.* Facial Plastic Surgery, 1989. **6**(2): p. 108-112.
100. Zabaneh, G., et al., *Rhinoplasty: a hands-on training module.* Plastic & Reconstructive Surgery, 2009. **124**(3): p. 952-4.
101. Weinfeld, A.B., *Chicken sternal cartilage for simulated septal cartilage graft carving: a rhinoplasty educational model.* Aesthetic Surgery Journal, 2010. **30**(6): p. 810-3.
102. Dini, G.M., et al., *Training rhinoseptoplasty, sinusectomy, and turbinectomy in an animal model.* Plastic & Reconstructive Surgery, 2012. **130**(1): p. 224e-226e.
103. Valente, D.S., et al., *Telemedicine and Plastic Surgery: A Pilot Study.* Plast Surg Int, 2015. **2015**: p. 187505.
104. Thompson, L.W., et al., *A simplified art course for the plastic surgeon.* Plastic & Reconstructive Surgery, 1972. **49**(4): p. 408-10.
105. Guneron, E., et al., *Aesthetic surgery training: The role of art education.* Aesthetic Surgery Journal, 2005. **25**(1): p. 84-86.
106. Shepherd, L., *Practical sculptural training for the plastic surgeon.* International Journal of Surgery, 2005. **3**(1): p. 93-97.
107. Cingi, C. and F. Oghan, *Teaching 3D sculpting to facial plastic surgeons.* Facial Plastic Surgery Clinics of North America, 2011. **19**(4): p. 603-14, viii.
108. Iqbal, A., et al., *Discard little, learn more: the real tissue training model.* Plast Reconstr Surg, 2005. **115**(3): p. 948-9.
109. Esteban, D., et al., *Basic plastic surgery training using human skin.* Plastic & Reconstructive Surgery, 2009. **123**(2): p. 90e-92e.
110. Tadiparthi, S., S. Azad, and K. Graham, *A simple teaching aid for taking multiple skin grafts with a dermatome.* European Journal of Plastic Surgery, 2007. **29**(8): p. 385-386.
111. Bates, A.S., C.R. Davis, and A.J. Williams, *Medical student manikins - free plastic surgery training for super models.* Burns (03054179), 2014. **40**(3): p. 527-528.
112. Hicdonmez, T., T. Parsak, and S. Cobanoglu, *Simulation of surgery for craniosynostosis: a training model in a fresh cadaveric sheep cranium. Technical note.* Journal of Neurosurgery, 2006. **105**(2 Suppl): p. 150-2.
113. Schendel, S.A. and K. Montgomery, *A web-based, integrated simulation system for craniofacial surgical planning.* Plastic and Reconstructive Surgery, 2009. **123**(3): p. 1099-1106.
114. Ibrahim, A.M., et al., *Intraoperative CT: A teaching tool for the management of complex facial fracture fixation in surgical training.* Journal of Surgical Education, 2011. **68**(5): p. 437-41.
115. Coelho, G., et al., *Anatomical pediatric model for craniosynostosis surgical training.* Childs Nervous System, 2014. **30**(12): p. 2009-14.
116. Pfaff, A.J., *Pig eyelid as a teaching model for eyelid margin repair.* Ophthal Plast Reconstr Surg, 2004. **20**(5): p. 383-4.
117. Uygur, S., et al., *Sheep head model for plastic surgery training.* Plastic & Reconstructive Surgery, 2013. **132**(5): p. 895e-896e.
118. Gauba, V., G.M. Saleh, and S. Goel, *Ophthalmic plastic surgical skills assessment tool.* Ophthalmic Plastic & Reconstructive Surgery, 2008. **24**(1): p. 43-6.

119. Cohen, M., et al., *Teaching model for closure of oronasal fistula and bone grafting of the maxilla.* Cleft Palate-Craniofacial Journal, 1996. **33**(3): p. 198-201.
120. Matthews, M.S., *A teaching device for Furlow palatoplasty.* Cleft Palate Craniofac J, 1999. **36**(1): p. 64-6.
121. Liu, M.M., J. Kim, and N. Jabbour, *Teaching Furlow palatoplasty: The sticky note method.* International Journal of Pediatric Otorhinolaryngology, 2014. **78**(11): p. 1849-1851.
122. Zbar, R.I., et al., *Web-based medicine as a means to establish centers of surgical excellence in the developing world.* Plastic & Reconstructive Surgery, 2001. **108**(2): p. 460-5.
123. Zheng, Y., et al., *CAD/CAM silicone simulator for teaching cheiloplasty: Description of the technique.* British Journal of Oral and Maxillofacial Surgery, 2015. **53**(2): p. 194-196.
124. Pappachan, B., et al., *Learning model for palatal closure.* J Plast Reconstr Aesthet Surg, 2006. **59**(4): p. 439-40.
125. Vadodaria, S., et al., *The first cleft palate simulator.* Plast Reconstr Surg, 2007. **120**(1): p. 259-61.
126. Nagy, K. and M.Y. Mommaerts, *Advanced S(t)imulator for cleft palate repair techniques.* Cleft Palate-Craniofacial Journal, 2009. **46**(1): p. 1-5.
127. Wright, E.J., et al., *Cleft Lip Standardized Patient Examinations: The Role in Plastic Surgery Resident Education.* Cleft Palate Craniofac J, 2015.
128. Hoeyberghs, J.L. and A.F.S. Flemming, *Flexor tendon repair in perfect safety. A model for student practice.* European Journal of Plastic Surgery, 1994. **17**(4): p. 215-217.
129. Tare, M., *Dental rolls: a suitable model for practising tendon repair techniques.* J Hand Surg Br, 2004. **29**(5): p. 506-7.
130. Bremner, N.A. and M. Ellabban, *A re-usable model for teaching and practising tendon repair techniques.* J Hand Surg Eur Vol, 2007. **32**(6): p. 726.
131. Kamath, J., et al., *Flexor tendon repair simulator.* Tech Hand Up Extrem Surg, 2009. **13**(2): p. 117-8.
132. Ingraham, J.M., R.A. Weber, 3rd, and R.A. Weber, *Utilizing a simulated tendon to teach tendon repair technique.* Hand (N Y), 2009. **4**(2): p. 150-5.
133. Ingraham, J.M., R.A. Weber, 3rd, and R.A. Weber, *How we teach tendon repairs outside the operating room.* Plastic & Reconstructive Surgery, 2010. **125**(6): p. 266e-7e.
134. Rhodes, N.D., P.A. Wilson, and S.J. Southern, *The flexor-tendon repair simulator.* Br J Plast Surg, 2001. **54**(4): p. 373-4.
135. Smith, A.M., et al., *The porcine forelimb as a model for human flexor tendon surgery.* J Hand Surg Br, 2005. **30**(3): p. 307-9.
136. Bari, A.S., et al., *Overcoming the learning curve: a curriculum-based model for teaching zone II flexor tendon repairs.* Plastic & Reconstructive Surgery, 2012. **130**(2): p. 381-8.
137. Skoff, H.D., *A model for training in elevation of local skin flaps in the hand.* Journal of Hand Surgery - British Volume, 1994. **19**(6): p. 794-5.
138. Gilmour, A., R. Taghizadeh, and C.E. Payne, *The educational hand and head: novel teaching tools in the design and execution of local flaps.* J Plast Reconstr Aesthet Surg, 2012. **65**(7): p. 981-2.
139. Cochrane, J.P., et al., *Teaching aid in skin surgery.* Annals of the Royal College of Surgeons of England, 1991. **73**(5): p. 275.

140. Thornton, B.P., et al., *Doppler signal interpretation in free tissue transfer: A computer simulator for resident and nursing education.* Journal of Reconstructive Microsurgery, 2007. **23**(2): p. 75-78.
141. Barron, E.J. and Y. Godwin, *Peri-areolar marking in Lejour's mammoplasty-a simple device to aid trainee learning: The flexible curve.* European Journal of Plastic Surgery, 2011. **34**(5): p. 417-419.
142. Wexler, M.R., A. Giladi, and Z. Neuman, *Demonstrating the Z-plasty.* British Journal of Plastic Surgery, 1973. **26**(4): p. 417.
143. Labandter, H., *Teaching basic flap designs with sponge models.* British Journal of Plastic Surgery, 1976. **29**(1): p. 14-5.
144. Maher, I.A., M. Boyle, and M. Abdelmalek, *Use of latex-free elastic bandage to simulate flap mechanics.* Dermatologic Surgery, 2010. **36**(1): p. 113-4.
145. Garcia, C., R. Haque, and E. Poletti, *Surgical pearl: artificial skin model for simulation of flap mechanics.* J Am Acad Dermatol, 2005. **53**(1): p. 143-4.
146. Sillitoe, A.T. and A. Platt, *The Z-plasty simulator.* Ann R Coll Surg Engl, 2004. **86**(4): p. 304-5.
147. Chipp, E. and S. Rayatt, *The stoke flap model for training in local flap surgery.* J Plast Reconstr Aesthet Surg, 2011. **64**(6): p. 836-7.
148. Tehrani, H., et al., *A novel training model for Mohs surgeons.* Dermatologic Surgery, 2012. **38**(6): p. 958-9.
149. Bjellerup, M., *Novel method for training skin flap surgery: polyurethane foam dressing used as a skin equivalent.* Dermatologic surgery : official publication for American Society for Dermatologic Surgery [et al.], 2005. **31**(9 Pt 1): p. 1107-1111.
150. Altinyazar, H.C., et al., *A training model for cutaneous surgery.* Dermatologic Surgery, 2003. **29**(11): p. 1122-4.
151. Dinsmore, R.C. and J.H. North, *Basic skin flaps for the general surgeon: a teaching method.* Southern medical journal, 2000. **93**(8): p. 783-786.
152. Liew, S.H., et al., *A non-animal facial model for teaching local flaps to trainees.* British Journal of Plastic Surgery, 2004. **57**(4): p. 374-5.
153. Nykiel, M., R. Wong, and G. Lee, *An economical training model to teach and practice deep inferior epigastric artery perforator dissection.* Annals of Plastic Surgery, 2014. **72 Suppl 1**: p. S66-70.
154. Townend, J., *A template for the planning of rhombic skin flaps.* Plast Reconstr Surg, 1993. **92**(5): p. 968-71.
155. Jovanovic, M.D. and M.M. Colic, *Design of the Limberg flap by a specially designed ruler: A personal approach.* Plastic and Reconstructive Surgery, 2004. **113**(2): p. 653-658.
156. Hassan, Z., F. Hogg, and K. Graham, *A 3-dimensional model for teaching local flaps using porcine skin.* Annals of Plastic Surgery, 2014. **73**(4): p. 362-3.
157. Khalil, P.N., et al., *Teaching advanced wound closure techniques using cattle digits.* Dermatologic Surgery, 2011. **37**(3): p. 325-330.
158. Nistor, A., et al., *Mastering the approach of internal mammary vessels: a new training model in pigs.[Erratum appears in Plast Reconstr Surg. 2013 Jun;131(6):1443].* Plastic & Reconstructive Surgery, 2013. **131**(5): p. 859e-61e.
159. Demirseren, M.E., et al., *Excised abdominoplasty material as a systematic plastic surgical training model.* Plastic Surgery International Print, 2012. **2012**: p. 834212.

160. Carey, J.N., et al., *Simulation of plastic surgery and microvascular procedures using perfused fresh human cadavers.* J Plast Reconstr Aesthet Surg, 2014. **67**(2): p. e42-8.
161. Wolff, K.D., et al., *Flap raising on pulsatile perfused cadaveric tissue: A novel method for surgical teaching and exercise.* Journal of Cranio-Maxillofacial Surgery, 2014. **42**(7): p. 1423-1427.
162. Patel, U.A., S.W. Bayles, and R.E. Hayden, *The submental flap: A modified technique for resident training.* Laryngoscope, 2007. **117**(1): p. 186-9.
163. Farber, N., et al., *"Wet behind the ears": the postauricular training ground for local flaps.* Journal of Drugs in Dermatology: JDD, 2012. **11**(11): p. 1358-60.
164. Stern, C., et al., *Integration of surgical simulation in plastic surgery residency training.* Studies in Health Technology & Informatics, 2012. **173**: p. 497-9.
165. Shewaga, R., et al., *Z-DOC: a serious game for Z-plasty procedure training.* Studies in Health Technology & Informatics, 2013. **184**: p. 404-6.
166. Yamada, A., et al., *New training method of creating ear framework by using precise copy of costal cartilage.* Journal of Craniofacial Surgery, 2009. **20**(3): p. 899-902.
167. Shin, H.S. and S.C. Hong, *A porcine rib cartilage model for practicing ear-framework fabrication.* Journal of Craniofacial Surgery, 2013. **24**(5): p. 1756-7.
168. Hultman, C.S., et al., *Sometimes you can't make it on your own: the impact of a professionalism curriculum on the attitudes, knowledge, and behaviors of an academic plastic surgery practice.* J Surg Res, 2013. **180**(1): p. 8-14.
169. Roostaeian, J., J. Rough, and M.C. Edwards, *A plastic surgery resident's view of aesthetic training and the future.* Aesthet Surg J, 2014. **34**(8): p. 1270-3.
170. Baker, T.J. and H.L. Gordon, *The Training of Aesthetic Surgeons in a Private Practice.* Plastic and Reconstructive Surgery Plastic and Reconstructive Surgery, 1981. **68**(5): p. 774-775.
171. Williams, H.B., *Aesthetic plastic surgery education.* Canadian Journal of Plastic Surgery, 1994. **2**(1): p. 13-15.
172. Linder, S.A., I.J.A. Mele, and A. Capozzi, *Teaching aesthetic surgery at the resident level.* Aesthetic Plastic Surgery, 1996. **20**(4): p. 351-354.
173. Smith, J., A. Kilshaw, and A. Williams, *UKTEAS: United Kingdom training experience in aesthetic surgery.* Journal of Plastic, Reconstructive & Aesthetic Surgery, 2016. **69**(7): p. 1008-1009.
174. Morrison, C.M., et al., *A survey of cosmetic surgery training in plastic surgery programs in the United States.* Plast Reconstr Surg, 2008. **122**(5): p. 1570-8.
175. Edwards, K. and C. Ishii, *Cosmetic surgery training in the United States.* Aesthet Surg J, 2011. **31**(8): p. 980-1.
176. Taub, P.J., L. David, and J.E. Cheesborough, *Curriculum Development for the Resident Aesthetic Clinic.* Plastic and Reconstructive Surgery – Global Open, 2015. **3**(3): p. e365.
177. Kraft, C.T., M.S. Harake, and J.E. Janis, *Longitudinal Assessment of Aesthetic Plastic Surgery Training in the United States: The Effect of Increased ACGME Case Log Minimum Requirements.* Aesthet Surg J, 2018.
178. *The plastic surgery milestone project.* J Grad Med Educ, 2014. **6**(1 Suppl 1): p. 225-42.
179. Hultman, C.S., et al., *Identification of Best Practices for Resident Aesthetic Clinics in Plastic Surgery Training: The ACAPS National Survey.* Plast Reconstr Surg Glob Open, 2015. **3**(3): p. e370.

180. Momeni, A., et al., *The quality of aesthetic surgery training in plastic surgery residency: a survey among residents in Germany.* Annals of plastic surgery, 2013. **70**(6): p. 704-708.
181. Pu, L.L.Q., et al., *Resident Aesthetic Surgery Training: The University of South Florida Model.* Aesthetic Surgery Journal, 1999. **19**(6): p. 465-468.
182. Baker, T.J. and H.L. Gordon, *The Training of Aesthetic Surgeons in a Private Practice.* Plastic and Reconstructive Surgery, 1981. **68**(5): p. 774-775.
183. Zucker, J., et al., *Measuring and assessing preventive medicine services in a student-run free clinic.* J Health Care Poor Underserved, 2013. **24**(1): p. 344-58.
184. Neaman, K.C., et al., *Plastic surgery chief resident clinics: the current state of affairs.* Plast Reconstr Surg, 2010. **126**(2): p. 626-33.
185. Freiberg, A., *Challenges in developing resident training in aesthetic surgery.* Ann Plast Surg, 1989. **22**(3): p. 184-7.
186. Schulman, N.H., *Aesthetic surgical training: the Lenox Hill model.* Annals of Plastic Surgery, 1997. **38**(4): p. 309-13.
187. Krieger, L.M. and W.W. Shaw, *Pricing strategy for aesthetic surgery: economic analysis of a resident clinic's change in fees.* Plast Reconstr Surg, 1999. **103**(2): p. 695-700.
188. Pyle, J.W., et al., *Outcomes analysis of a resident cosmetic clinic: safety and feasibility after 7 years. [Review] [39 refs].* Annals of Plastic Surgery, 2010. **64**(3): p. 270-4.
189. May, J.W., Jr., *Aesthetic surgery 101: resident education in aesthetic surgery, the MGH experience.* Ann Plast Surg, 2003. **50**(6): p. 561-6.
190. Pu, L.L., B.P. Thornton, and H.C. Vasconez, *The educational value of a resident aesthetic surgery clinic: a 10-year review.* Aesthetic Surgery Journal, 2006. **26**(1): p. 41-4.
191. Koulaxouzidis, G., et al., *Aesthetic surgery performed by plastic surgery residents: an analysis of safety and patient satisfaction.* Ann Plast Surg, 2014. **73**(6): p. 696-700.
192. Day, K.M., et al., *Progressive Surgical Autonomy in a Plastic Surgery Resident Clinic.* Plast Reconstr Surg Glob Open, 2017. **5**(5): p. e1318.
193. Ingargiola, M.J., et al., *Plastic Surgery Resident-Run Cosmetic Clinics: A Survey of Current Practices.* Aesthet Surg J, 2018.
194. Qureshi, A.A., et al., *Resident Cosmetic Clinic: Practice Patterns, Safety, and Outcomes at an Academic Plastic Surgery Institution.* Aesthet Surg J, 2016. **36**(9): p. Np273-80.
195. Stadelmann, W.K., et al., *Residency training in aesthetic surgery: maximizing the residents' experience.* Plast Reconstr Surg, 1998. **101**(7): p. 1973-7.
196. Mahabir, R.C., et al., *Aesthetic Plastic Surgery Education: The Vancouver Approach.* Canadian Journal of Plastic Surgery Canadian Journal of Plastic Surgery, 2002. **10**(1): p. 11-14.
197. Whitaker, I.S., et al., *An analysis of 1361 aesthetic procedures from 2000 to 2005 in a large regional plastic surgery unit: implications for cosmetic surgery training.* J Plast Reconstr Aesthet Surg, 2007. **60**(4): p. 437-9.
198. Freiberg, A., et al., *Are patients satisfied with results from residents performing aesthetic surgery?* Plastic and Reconstructive Surgery, 1997. **100**(7): p. 1824-1831.
199. Zweifler, M. and S.B. Glasberg, *An outcome-based study of aesthetic surgery in a clinic setting.* Annals of Plastic Surgery, 2000. **44**(4): p. 355-360.
200. Rezaeian, F., et al., *Training in aesthetic surgery at a University Clinic - The "munich model". [German].* Handchirurgie Mikrochirurgie Plastische Chirurgie, 2013. **45**(6): p. 370-375.

201. Jubbal, K.T., et al., *The impact of resident involvement in breast reconstruction surgery outcomes by modality: An analysis of 4,500 cases.* Microsurgery, 2017.
202. Kazaure, H.S., S.A. Roman, and J.A. Sosa, *The resident as surgeon: an analysis of ACS-NSQIP.* Journal of Surgical Research, 2012. **178**(1): p. 126-32.
203. Papandria, D., et al., *Assessing trainee impact on operative time for common general surgical procedures in ACS-NSQIP.* Journal of Surgical Education, 2012. **69**(2): p. 149-55.
204. Jordan, S.W., et al., *Resident involvement and plastic surgery outcomes: an analysis of 10,356 patients from the American College of Surgeons National Surgical Quality Improvement Program database.* Plastic & Reconstructive Surgery, 2013. **131**(4): p. 763-73.
205. Rao, V.K., et al., *Establishing a multidisciplinary academic cosmetic center.* Plast Reconstr Surg, 2011. **128**(6): p. 741e-6e.
206. Bennett Katelyn, G.K., *The Teaching of Ethics and Professionalism in Plastic Surgery Residency: A Cross-Sectional Survey.* Annals of Plastic Surgery. **78**(5): p. 552-556.
207. AlGhamdi, K.M., et al., *Perceptions, attitudes, and satisfaction concerning resident participation in health care among dermatology outpatients.* J Cutan Med Surg, 2014. **18**(1): p. 20-7.
208. Kempenich, J.W., et al., *The Effect of Patient Education on the Perceptions of Resident Participation in Surgical Care.* J Surg Educ, 2016. **73**(6): p. e111-e117.
209. Brandel, M.G., et al., *Efficacy of a Procedure-Specific Education Module on Informed Consent in Plastic Surgery.* Ann Plast Surg, 2017. **78**(5 Suppl 4): p. S225-S228.
210. Ching, S., et al., *Measuring outcomes in aesthetic surgery: a comprehensive review of the literature.* Plast Reconstr Surg, 2003. **111**(1): p. 469-80; discussion 481-2.
211. Bingham, H.G., *Training in esthetic surgery: some problems encountered in a university program.* Plast Reconstr Surg, 1980. **65**(2): p. 227-8.
212. Chivers, Q.J., et al., *Cosmetic surgery training in Canadian plastic surgery residencies: are we training competent surgeons?* Aesthet Surg J, 2013. **33**(1): p. 160-5.
213. Oni, G., et al., *Cosmetic surgery training in plastic surgery residency programs in the United States: How have we progressed in the last three years?* Aesthetic Surgery Journal, 2011. **31**(4): p. 445-455.
214. Hashem, A.M., et al., *Resident and Program Director Perceptions of Aesthetic Training in Plastic Surgery Residency: An Update.* Aesthet Surg J, 2017.
215. Boyle, K.R., et al., *Resident education of documentation and coding.* Otolaryngology - Head and Neck Surgery, 2011. **145**: p. 136.
216. Raper Steven, E.S., *Tipping the scales: educating surgeons about medical malpractice.* Journal of Surgical Research, 2016. **206**(1): p. 206-213.
217. Ghaderi Kimeya, F.K., *Coding and Billing in Surgical Education: A Systems-Based Practice Education Program.* Journal of Surgical Education, 2017. **74**(2): p. 199-202.
218. Kamali, P., et al., *Plastic Surgery Training Worldwide: Part 1. The United States and Europe.* Plast Reconstr Surg Glob Open, 2016. **4**(3): p. e641.
219. Swing, S.R., et al., *Educational milestone development in the first 7 specialties to enter the next accreditation system.* J Grad Med Educ, 2013. **5**(1): p. 98-106.
220. Nasca, T.J., et al., *The Next GME Accreditation System — Rationale and Benefits.* New England Journal of Medicine, 2012. **366**(11): p. 1051-1056.

221. Byrne, L.M., R.S. Miller, and T.J. Nasca, *Implementing the Next Accreditation System: Results of the 2014-2015 Annual Data Review.* J Grad Med Educ, 2016. **8**(1): p. 118-23.
222. Qureshi, A.A., et al., *Nonsurgical Facial Rejuvenation: Outcomes and Safety of Neuromodulator and Soft-Tissue Filler Procedures Performed in a Resident Cosmetic Clinic.* Aesthetic Plastic Surgery, 2017: p. 25.
223. Brandel, M.G., et al., *Analysis of a Resident Aesthetic Clinic: Process for Rhinoplasty, Resident Experience, and Patient Satisfaction.* Annals of Plastic Surgery, 2017. **78**(5 Suppl 4): p. S175-S179.
224. Rad, A., et al. *The chief resident aesthetic surgery clinic: a safe alternative for patients*. in *Abstract presented at the 91st Annual Meeting of the American Society of Plastic Surgeons. San Francisco, Calif.* 2012.
225. Janis, J.E., *Discussion: 360-Degree evaluations of plastic surgery resident accreditation council for graduate medical education competencies: experience using a short form.* Plast Reconstr Surg, 2008. **122**(2): p. 650-1.
226. Pollock, R.A., et al., *360-degree evaluations of plastic surgery resident accreditation council for graduate medical education competencies: experience using a short form.* Plast Reconstr Surg, 2008. **122**(2): p. 639-49.
227. Connolly Katharine, A.K., *Feedback in Plastic and Reconstructive Surgery Education: Past, Present, and Future.* Journal of Craniofacial Surgery. **26**(8): p. 2261-3.
228. Ellis, H., *The private hospital and the surgical trainee.* Br Med J (Clin Res Ed), 1988. **296**(6616): p. 152.
229. Statistics, A.N.C.o.P.S.P. *2014 Plastic Surgery Statistics Report*. 2014 [cited 2014 October 26, 2015]; Available from: http://www.plasticsurgery.org/Documents/news-resources/statistics/2014-statistics/plastic-surgery-statsitics-full-report.pdf.
230. Ferron, C.E., et al., *Recent Canadian plastic surgery graduates: are they prepared for the real world?* Plast Reconstr Surg, 2010. **125**(3): p. 1031-6.
231. Sterodimas, A., H.N. Radwanski, and I. Pitanguy, *Aesthetic plastic surgery: junior plastic surgeons' confidence in a training program.* Aesthetic Plast Surg, 2009. **33**(1): p. 131-2.
232. Sheckter, C.C., et al., *Incorporation of fresh tissue surgical simulation into plastic surgery education: maximizing extraclinical surgical experience.* J Surg Educ, 2013. **70**(4): p. 466-74.
233. Adams, W.P., Jr. and P. Mallucci, *Breast augmentation.* Plast Reconstr Surg, 2012. **130**(4): p. 597e-611e.
234. Alpert, B.S. and D.H. Lalonde, *MOC-PS(SM) CME article: breast augmentation.* Plast Reconstr Surg, 2008. **121**(4 Suppl): p. 1-7.
235. Gorney, M., *Preventing litigation in breast augmentation.* Clin Plast Surg, 2001. **28**(3): p. 607-15.
236. Paik, A.M., et al., *Beyond the operating room: a look at legal liability in body contouring procedures.* Aesthet Surg J, 2014. **34**(1): p. 106-13.
237. Paik, A.M., et al., *A look inside the courtroom: an analysis of 292 cosmetic breast surgery medical malpractice cases.* Aesthet Surg J, 2014. **34**(1): p. 79-86.
238. Marchesi, A., et al., *Mammaplasties and medicolegal issues: 50 cases of litigation in aesthetic surgery of the breast.* Aesthetic Plast Surg, 2012. **36**(1): p. 122-7.
239. Mavroforou, A., A. Giannoukas, and E. Michalodimitrakis, *Medical litigation in cosmetic plastic surgery.* Med Law, 2004. **23**(3): p. 479-88.

240. Regenbogen, S.E., et al., *Patterns of technical error among surgical malpractice claims: an analysis of strategies to prevent injury to surgical patients.* Ann Surg, 2007. **246**(5): p. 705-11.
241. Gorney, M., *Avoiding litigation in breast modification.* Plast Reconstr Surg, 2011. **127**(5): p. 2113-5.
242. Madani, A., et al., *What Are the Principles That Guide Behaviors in the Operating Room?: Creating a Framework to Define and Measure Performance.* Ann Surg, 2016.
243. Yule, S., et al., *Development of a rating system for surgeons' non-technical skills.* Med Educ, 2006. **40**(11): p. 1098-104.
244. Madani, A., et al., *Expert Intraoperative Judgment and Decision-Making: Defining the Cognitive Competencies for Safe Laparoscopic Cholecystectomy.* Journal of the American College of Surgeons, 2015.
245. Van Herzeele, I., et al., *Cognitive training improves clinically relevant outcomes during simulated endovascular procedures.* J Vasc Surg, 2008. **48**(5): p. 1223-30, 1230 e1.
246. Tang, B., G.B. Hanna, and A. Cuschieri, *Analysis of errors enacted by surgical trainees during skills training courses.* Surgery, 2005. **138**(1): p. 14-20.
247. Pugh, C.M. and D.A. DaRosa, *Use of cognitive task analysis to guide the development of performance-based assessments for intraoperative decision making.* Mil Med, 2013. **178**(10 Suppl): p. 22-7.
248. Clark, R.E.a.E., F, *Cognitive task analysis.* International Journal of Educational Research, 1996. **5**(25): p. 403-417.
249. Pugh, C.M., et al., *Intra-operative decision making: more than meets the eye.* J Biomed Inform, 2011. **44**(3): p. 486-96.
250. Charness, N., R.R. Hoffman, and P.J. Feltovich, *Cambridge Handbook of Expertise and Expert Performance, The*, ed. K.A. Ericsson. 2006: Cambridge University Press.
251. Tebbetts, J.B., *Augmentation mammaplasty redefining the patient and surgeon experience.* 2010.
252. Walden, J.L., *Breast augmentation*, in *Aesthetic plastic surgery*, S.J. Aston, D.S. Steinbrech, and J.L. Walden, Editors. 2009, Saunders Elsevier: Philadelphia. p. 661-673.
253. Hedén, P., *Breast Augmentation*, in *Plastic Surgery: Indications and Practice*, B. Guyuron, Editor. 2009, Saunders/Elsevier: Edinburgh. p. 1561-1574.
254. *Plastic Surgery Education Network*. 2014 [cited 2014; Available from: http://www.psenetwork.org/.
255. Hidalgo, D.A. and J.A. Spector, *Breast augmentation.* Plast Reconstr Surg, 2014. **133**(4): p. 567e-83e.
256. Tebbetts, J.B. and W.P. Adams, *Five critical decisions in breast augmentation using five measurements in 5 minutes: the high five decision support process.* Plast Reconstr Surg, 2005. **116**(7): p. 2005-16.
257. Tebbetts, J.B. and W.P. Adams, *Five critical decisions in breast augmentation using five measurements in 5 minutes: the high five decision support process.* Plast Reconstr Surg, 2006. **118**(7 Suppl): p. 35S-45S.
258. Namnoum, J.D., et al., *Primary breast augmentation clinical trial outcomes stratified by surgical incision, anatomical placement and implant device type.* J Plast Reconstr Aesthet Surg, 2013. **66**(9): p. 1165-72.

259. Tebbetts, J.B., *A system for breast implant selection based on patient tissue characteristics and implant-soft tissue dynamics.* Plast Reconstr Surg, 2002. **109**(4): p. 1396-409; discussion 1410-5.
260. Berry, M.G., V. Cucchiara, and D.M. Davies, *Breast augmentation: Part III--preoperative considerations and planning.* J Plast Reconstr Aesthet Surg, 2011. **64**(11): p. 1401-9.
261. Walden, J.L., G. Panagopoulous, and S.W. Shrader, *Contemporary decision making and perception in patients undergoing cosmetic breast augmentation.* Aesthet Surg J, 2010. **30**(3): p. 395-403.
262. Codner, M.A., A.T. Cohen, and T.R. Hester, *Complications in breast augmentation: prevention and correction.* Clin Plast Surg, 2001. **28**(3): p. 587-95; discussion 596.
263. Choudry, U. and N. Kim, *Preoperative assessment preferences and reported reoperation rates for size change in primary breast augmentation: a survey of ASPS members.* Plast Reconstr Surg, 2012. **130**(6): p. 1352-9.
264. Dyer, C., *Clinical negligence claims against plastic surgeons rise "significantly".* BMJ, 2012. **344**: p. e298.
265. Richards, E. and R. Vijh, *Analysis of malpractice claims in breast care for poor cosmetic outcome.* Breast, 2011. **20**(3): p. 225-8.
266. Mehta, S., J. Farhadi, and A. Atrey, *A review of litigation in plastic surgery in England. Lessons learned.* J Plast Reconstr Aesthet Surg, 2010. **63**(10): p. 1747-8.
267. Jena, A.B., et al., *Malpractice risk according to physician specialty.* N Engl J Med, 2011. **365**(7): p. 629-36.
268. Rennie, S.C., et al., *Defining decision making: a qualitative study of international experts' views on surgical trainee decision making.* World J Surg, 2011. **35**(6): p. 1214-20.
269. De Cossart L, F.D., *Cultivating a Thinking Surgeon: New Perspectives on Clinical Teaching, Learning and Assessment*. 2005, Harley, Nr Shrewsbury, United Kingdom: TFM Pub.
270. Rohrich, R.J. and D.F. Johns, *The Socratic method in plastic surgery education: a lost art revisited.* Plast Reconstr Surg, 2000. **105**(5): p. 1803-5.
271. Rinker, B., M. Donnelly, and H.C. Vasconez, *Teaching patient selection in aesthetic surgery: use of the standardized patient.* Ann Plast Surg, 2008. **61**(2): p. 127-31; discussion 132.
272. Sullivan, M.E., et al., *The use of cognitive task analysis to reveal the instructional limitations of experts in the teaching of procedural skills.* Acad Med, 2014. **89**(5): p. 811-6.
273. Yates, K., M. Sullivan, and R. Clark, *Integrated studies on the use of cognitive task analysis to capture surgical expertise for central venous catheter placement and open cricothyrotomy.* Am J Surg, 2012. **203**(1): p. 76-80.
274. Crebbin, W., S.W. Beasley, and D.A.K. Watters, *Clinical decision making: how surgeons do it.* ANZ Journal of Surgery, 2013. **83**(6): p. 422-428.
275. Strull, W.M., B. Lo, and G. Charles, *Do patients want to participate in medical decision making?* JAMA, 1984. **252**(21): p. 2990-4.
276. Ubbink, D.T., T.B. Santema, and O. Lapid, *Shared Decision-Making in Cosmetic Medicine and Aesthetic Surgery.* Aesthet Surg J, 2015.

277. Ubbink, D.T., M.G. Hageman, and D.A. Legemate, *Shared Decision-Making in Surgery.* Surg Technol Int, 2015. **26**: p. 31-6.
278. Hess, E.P., et al., *Shared Decision-making in the Emergency Department: Respecting Patient Autonomy When Seconds Count.* Acad Emerg Med, 2015. **22**(7): p. 856-64.
279. Legare, F., et al., *Interventions for improving the adoption of shared decision making by healthcare professionals.* Cochrane Database Syst Rev, 2010(5): p. CD006732.
280. Fitts, P.M., *Factors in complex skill training*, in *Training research and education* 1962, University of Pittsburgh Press: Pittsburgh. p. 177-197.
281. Kazan, R., et al., *The Montreal Augmentation Mammoplasty Operation (MAMO) Simulator: An Alternative Method to Train and Assess Competence in Breast Augmentation Procedures.* Aesthet Surg J, 2018.
282. Madani, A., et al., *Measuring Decision-Making During Thyroidectomy: Validity Evidence for a Web-Based Assessment Tool.* World J Surg, 2018. **42**(2): p. 376-383.
283. Madani, A., et al., *Measuring intra-operative decision-making during laparoscopic cholecystectomy: validity evidence for a novel interactive Web-based assessment tool.* Surg Endosc, 2017. **31**(3): p. 1203-1212.
284. Satava, R.M., A.G. Gallagher, and C.A. Pellegrini, *Surgical competence and surgical proficiency: definitions, taxonomy, and metrics.* J Am Coll Surg, 2003. **196**(6): p. 933-7.
285. FC, S., *Teaching and measuring surgical techniques — the technical evaluation of competence.* Bull Am Coll of Surg, 1978(63): p. 9-14.
286. Satava, R.M., *Identification and reduction of surgical error using simulation.* Minim Invasive Ther Allied Technol, 2005. **14**(4): p. 257-61.
287. Bell, R.H., Jr., *Why Johnny cannot operate.* Surgery, 2009. **146**(4): p. 533-42.
288. Shuell, T.J., *Phases of Meaningful Learning.* Review of Educational Research, 1990. **60**(4): p. 531-47.
289. Flin, R., G. Youngson, and S. Yule, *How do surgeons make intraoperative decisions?* Qual Saf Health Care, 2007. **16**(3): p. 235-9.
290. Silvestre, J., et al., *The Plastic Surgery Hand Curriculum.* Plast Reconstr Surg, 2015. **136**(6): p. 1239-47.
291. Gray, S.A., et al. *Mental Modeler: A Fuzzy-Logic Cognitive Mapping Modeling Tool for Adaptive Environmental Management*. in *System Sciences (HICSS), 2013 46th Hawaii International Conference on*. 2013.
292. Darisi, T., S. Thorne, and C. Iacobelli, *Influences on decision-making for undergoing plastic surgery: a mental models and quantitative assessment.* Plast Reconstr Surg, 2005. **116**(3): p. 907-16.
293. Byram, S., et al., *Mental models of women with breast implants: local complications.* Behav Med, 2001. **27**(1): p. 4-14.
294. Kruser, J.M., et al., *"And I think that we can fix it": mental models used in high-risk surgical decision making.* Ann Surg, 2015. **261**(4): p. 678-84.
295. Dy, C.J., et al., *The epidemiology of reoperation after flexor tendon repair.* J Hand Surg Am, 2012. **37**(5): p. 919-24.
296. Dy, C.J., et al., *Complications after flexor tendon repair: a systematic review and meta-analysis.* J Hand Surg Am, 2012. **37**(3): p. 543-551 e1.
297. Hill, C., et al., *A regional audit of hand and wrist injuries. A study of 4873 injuries.* J Hand Surg Br, 1998. **23**(2): p. 196-200.

298. Angermann, P. and M. Lohmann, *[Hand and wrist injuries. A study of 50.272 injuries].* Ugeskr Laeger, 1995. **157**(6): p. 734-7.
299. Austin, L.C. and B. Fischhoff, *Injury prevention and risk communication: a mental models approach.* Inj Prev, 2012. **18**(2): p. 124-9.
300. Saltzman, P.D., *Best Practices in Surgical Education: Innovations in Skills Training*. 2010: Ethicon Endo-Surgery, Incorporated.
301. Pu, L.L.Q., B.P. Thornton, and H.C. Vasconez, *The educational value of a resident aesthetic surgery clinic: A 10-year review.* Aesthetic Surgery Journal, 2006. **26**(1): p. 41-44.
302. Pyle, J.W., et al., *Outcomes analysis of a resident cosmetic clinic: safety and feasibility after 7 years.* Annals of Plastic Surgery, 2010. **64**(3): p. 270-4.
303. Pollock, R.A., et al., *360-degree evaluations of plastic surgery resident accreditation council for graduate medical education competencies: experience using a short form.* Plastic & Reconstructive Surgery, 2008. **122**(2): p. 639-49.
304. Halpenny, J., *The Training of the Surgeon.* Can Med Assoc J, 1918. **8**(10): p. 896-902.
305. Sullivan, M.E., et al., *The use of cognitive task analysis to improve the learning of percutaneous tracheostomy placement.* Am J Surg, 2007. **193**(1): p. 96-9.
306. Johnson, S.P., K.C. Chung, and J.F. Waljee, *Evidence-Based Education in Plastic Surgery.* Plast Reconstr Surg, 2015. **136**(2): p. 258e-266e.
307. Borsci, S., S. Federici, and M. Lauriola, *On the dimensionality of the System Usability Scale: a test of alternative measurement models.* Cogn Process, 2009. **10**(3): p. 193-7.
308. Brooke, J., *SUS: A 'Quick and Dirty' Usability Scale*, in *Usability Evaluation in Industry*, B.T. P. Jordan, and B. Weerdmeester, Editor. 1996, Taylor & Francis: London. p. 189–194.
309. Stranc, M.F., J.G. McDiarmid, and L.C. Stranc, *Video assessment of surgical technique.* British Journal of Plastic Surgery, 1991. **44**(1): p. 65-8.
310. Khan, M.S., et al., *Assessing surgical skill using bench station models.* Plastic & Reconstructive Surgery, 2007. **120**(3): p. 793-800.
311. Hull, L. and N. Sevdalis, *Advances in Teaching and Assessing Nontechnical Skills.* Surg Clin North Am, 2015. **95**(4): p. 869-84.
312. Wood, T.C., et al., *Training Tools for Nontechnical Skills for Surgeons-A Systematic Review.* J Surg Educ, 2017. **74**(4): p. 548-578.
313. Louridas, M., et al., *Randomized clinical trial to evaluate mental practice in enhancing advanced laparoscopic surgical performance.* BJS (British Journal of Surgery), 2015. **102**(1): p. 37-44.
314. Phitayakorn, R., et al., *Practicality of intraoperative teamwork assessments.* Journal of Surgical Research, 2014. **190**(1): p. 22-28.
315. Yule, S., et al., *Surgeons' Non-technical Skills in the Operating Room: Reliability Testing of the NOTSS Behavior Rating System.* World Journal of Surgery, 2008. **32**(4): p. 548-556.
316. *The Non-Technical Skills for Surgeons (NOTSS) System Handbook v1.2*. 1.2 ed. 2012, Aberdeen, Scotland: University of Aberdeen.
317. Chatterjee, S., et al., *Assessing the surgical decision making abilities of novice and proficient urologists.* J Urol, 2009. **181**(5): p. 2251-6.

318. Samuelson, M.L., J.A. Cadeddu, and E.D. Matsumoto, *Laparoscopic decision making: impact of preoperative reading and laparoscopic experience.* J Urol, 2006. **176**(4 Pt 1): p. 1553-7.
319. Dumestre, D., J.K. Yeung, and C. Temple-Oberle, *Evidence-based microsurgical skills acquisition series part 2: validated assessment instruments--a systematic review.* J Surg Educ, 2015. **72**(1): p. 80-9.
320. Riggle, J.D., et al., *Task analysis method for procedural training curriculum development.* Perspect Med Educ, 2014. **3**(3): p. 204-18.
321. Ounounou, E., et al., *Nontechnical Skills in Surgery: A Systematic Review of Current Training Modalities.* J Surg Educ, 2018.
322. Klein, G.A., R. Calderwood, and D. MacGregor, *Critical decision method for eliciting knowledge.* IEEE Trans. Syst., Man, Cybern. IEEE Transactions on Systems, Man, and Cybernetics, 1989. **19**(3): p. 462-472.
323. Starkes, J.L. and K.A. Ericsson, *Expert performance in sports : advances in research on sport expertise*. 2003, Champaign, IL: Human Kinetics.
324. Schraagen, J.M., S.F. Chipman, and V.L. Shalin, *Cognitive task analysis*. Expertise: research and applications. 2000, Mahwah, N.J.: L. Erlbaum Associates.
325. Canada, R.C.o.P.a.S.o. *SPECIFIC INFORMATION REGARDING THE ROYAL COLLEGE PLASTIC SURGERY EXAMINATION*. 2017 January 2017; Available from: http://www.royalcollege.ca/rcsite/documents/ibd/plastic-surgery-examinfo-e.pdf.
326. Surgery, T.A.B.o.P. *Overview of Oral Exam*. 2020.
327. Kazan, R., et al., *The Evolution of Surgical Simulation: The Current State and Future Avenues for Plastic Surgery Education.* Plast Reconstr Surg, 2017. **139**(2): p. 533e-543e.
328. Kazan, R., et al., *A Novel Mammoplasty Part-Task Trainer for Simulation of Breast Augmentation: Description and Evaluation.* Simul Healthc, 2016. **11**(1): p. 60-4.
329. Bachorowski, J.-A., *Vocal Expression and Perception of Emotion.* Current Directions in Psychological Science, 1999. **8**(2): p. 53-57.
330. Banerjee Dasgupta, P., *Detection and Analysis of Human Emotions through Voice and Speech Pattern Processing.* International Journal of Computer Trends and Technology, 2017. **52**.
331. Fenton-O'Creevy, M., et al., *Thinking, feeling and deciding: The influence of emotions on the decision making and performance of traders.* Journal of Organizational Behavior, 2011. **32**(8): p. 1044-1061.
332. Agnew, S.P. and G.A. Dumanian, *A simple test: please draw the incision. It is not as easy as we may think.* J Hand Surg Am, 2008. **33**(10): p. 1894-8.
333. Zucca-Matthes, G., G. Lebovic, and M. Lyra, *Mastotrainer new version: realistic simulator for training in breast surgery.* Breast, 2017. **31**: p. 82-84.
334. Aboelatta, Y.A., H. Aboelatta, and K. Elgazzar, *A Simple Method for Proper Placement of the Inframammary Fold Incision in Primary Breast Augmentation.* Ann Plast Surg, 2015. **75**(5): p. 497-502.
335. Shewaga, R., et al., *Z-DOC: a serious game for Z-plasty procedure training.* Stud Health Technol Inform, 2013. **184**: p. 404-6.
336. Schlachta, C.M., et al., *A novel method for assessing visual perception of surgical planes.* Can J Surg, 2015. **58**(2): p. 87-91.

337. Wu, F., et al., *A virtual training system for maxillofacial surgery using advanced haptic feedback and immersive workbench.* International Journal of Medical Robotics and Computer Assisted Surgery, 2014. **10**(1): p. 78-87.
338. Ali, S.T., R. Eagleson, and C.M. Schlachta, *Is Surgeons' Visual Perception of Tissue Planes a Learned Skill?* Journal of the American College of Surgeons, 2014. **219**(3, Supplement): p. S114.
339. Todd, S.A., et al., *Perceptions of facial aesthetics in two and three dimensions.* Eur J Orthod, 2005. **27**(4): p. 363-9.
340. Ashraf, A., et al., *Three-dimensional (3D) simulation versus two-dimensional (2D) enhances surgical skills acquisition in standardised laparoscopic tasks: a before and after study.* Int J Surg, 2015. **14**: p. 12-6.
341. Pikkel, D., A. Sharabi-Nov, and J. Pikkel, *The importance of side marking in preventing surgical site errors.* Int J Risk Saf Med, 2014. **26**(3): p. 133-8.
342. Rughani, M., M. Kokkinakis, and M. Davison, *Preoperative surgical marking: a case of seeing double.* BMJ Case Rep, 2010. **2010**.
343. Hirata, N., et al., *Importance of preoperative marking for minithoracotomy and for internal thoracic artery harvesting in minimally invasive direct coronary artery bypass grafting.* Surg Today, 2000. **30**(4): p. 400-2.
344. Bass, E.M., et al., *Does preoperative stoma marking and education by the enterostomal therapist affect outcome?* Dis Colon Rectum, 1997. **40**(4): p. 440-2.
345. Ghosh, S., et al., *Evaluation of surgeons' marking of excision margins for superficial facial skin cancer lesions.* J Laryngol Otol, 2009. **123**(2): p. 195-8.
346. Lalla, R., T.L. Brown, and R.W. Griffiths, *Where to draw the line: the error in marking surgical excision margins defined.* Br J Plast Surg, 2003. **56**(6): p. 603-6.
347. Miranda, B.H., M. Pywell, and D. Floyd, *A preoperative marking template for deep inferior epigastric artery perforator flap perforators in breast reconstruction.* Arch Plast Surg, 2014. **41**(2): p. 171-3.
348. Mitchell, N.M., et al., *A Real-Time Local Flaps Surgical Simulator Based on Advances in Computational Algorithms for Finite Element Models.* Plast Reconstr Surg, 2016. **137**(2): p. 445e-452e.