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Development of a Novel Gastrectomy Simulation Model for Bariatric Surgical Training

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Abstract

Objective: The field of bariatric surgery is an established field with neither a defined training scheme nor adequate artificial simulators. Many trainees are not exposed to the skill-set required in this subspecialty in general surgical training. We describe the development of a fully-functional gastric model which allows aspects of laparoscopic gastric band placement, sleeve gastrectomy and pouch formation of a Roux-en-Y gastric bypass.

Methods: The stomach model is made of pliable silicone with internal texturization to mimic stomach rugae. Mesh was used to simulate the greater and lesser omentum which was modified to allow diathermy division using various energy sources. The silicone allows for stapling with the thickest reload of gastric stapler and for suturing with braided polyglactic-acid sutures.

Results: Creation of the gastric simulator for bariatric surgery allowed the development of a highly functional component in simulated training of bariatric surgery. The described model allows re-creation of the three most common bariatric procedures to-date in a low-cost manner without use of animal materials which allows reproducible results in a standard laparoscopic box-trainer.

Conclusion: The proliferation of bariatric surgery worldwide would greatly benefit from a structured teaching methodology based around a low-cost, high-fidelity model. The model presented allows for demonstration and up-skilling in both resectional and restrictive bariatric surgical procedures. Demonstrable ability with performing each of these procedures on an artificial model could improve safety and quality of performance in the operating theatre.

Keywords: Bariatric surgery; Gastric surgery; Simulation; Surgical education

Introduction

The last century has seen a significant shift in the economy of time in surgical training. From the Halstedian model popularised in the U.S., the introduction of safe working hours has greatly limited contact time allowed to trainees in surgery. The European Working Time Directive in particular has restricted contact time to the point novel methods of training must be explored. In Australia, industrial guidelines enacted within enterprise agreements similarly have ensured the importance of the role of simulation in the formative years of surgical training. The dominance of private bariatric surgery stymies traditional training opportunities, hence the need for a simulation-based approach.

Simulation in surgery is not a new concept; aside from the time imperative upon trainees, the quality of performance of a surgical procedure can be uniquely demonstrated, practiced and assessed utilising non-patient models. The negative aspects of cadaveric models and animal models include their cost, potential transmissible diseases and licensing requirements which limits their usage to specialised centres with trained technicians. Artificial "dry" models allow for usage in clean or sterile environments in an easily reproducible manner with lesser issues of equity and access. Furthermore the concept of time as a surrogate marker of competence is no longer acceptable [1]. More scientifically-based assessment metrics via objective structured assessment tools are readily available and subject to rigorous construct validity [2].

The burgeoning nature of bariatric surgery worldwide has grown concomitantly with the exponential rise of the prevalence of obese patients for whom a surgical therapeutic measure is indicated. At present the most common three procedures are the sleeve gastrectomy, Roux-en-Y gastric bypass and the laparoscopically-placed gastric band. Each of these procedures requires a unique skillset which is not included in most generic surgical curricula and not practiced by trainees. The unfortunate nexus of these two phenomena results in most bariatric surgeons learning by the old "see one, do one" approach. As such the subspecialty is uniquely placed to benefit from a structured training program based around a cost-effective, reproducible artificial model as described here.

Material and Methods - Development and Refinement of the Model

The model was developed with the institutional approval of the Clinical Training and Evaluation Centre in Perth, Western Australia (CTEC) within The University of Western Australia. The initiation of designing a bariatric-specific model was instigated by the lack of appropriate models which accurately replicated the requirements for a sleeve gastrectomy; namely, a stomach with gastric liquid content, an accurate replication of the gastro-esophageal junction and an omentum which could be separated with a thermal energy device as is commonly used in laparoscopic sleeve gastrectomy.

Development of the Stomach Model

Silicone co-polymer was chosen as the modelling material given its pliability and customizable nature. Internal texturization to mimic stomach rugae was created, should the stomach be opened during resectional procedures. Each model used salmon-pink silicone. The material was easily manipulated into a construct resembling greater and lesser curvatures with Angle of His superiorly tapering to a simulated thickened pylorus. The internal diameter of the superior esophageal structure was sized over a 38 French bougie loosely to allow passage of a calibration device during the procedural components. An elasticised band was used over the esophageal structure onto plastic hose piping passed via an aperture in the superior aspect of the modified laparoscopic box trainer. Vessels mimicking gastric and gastro-epiploic vessels were drawn on with permanent marker with deliberate emphasis upon the incisura to ensure trainees were alerted to the significance of this, particularly for laparoscopic sleeve gastrectomy.

A layer of mesh was imbricated between the anterior and posterior leaves of the gastric model from the greater and lesser curvatures as seen in Figure 1. An added thin row of yellow silicon was added to mimic the closest aspect of the omentum at the greater curvature to give the impression of underlying gastro-epiploic arcades, also a marker for the surgical technique of sleeve gastrectomy. Finally the stomach was instilled with jelly-like liquid to simulate gastric contents should the stomach be opened during resectional surgery.

Figure 1: Stomach model *in-situ* with resectable omentum.

Refinement of Simulated Gastric Surgical Techniques

Given the requirement for surgical simulation each of the three most common surgical techniques in bariatric surgery had to be reproducible on the gastric model.

Diathermy utilising a stand-alone energy source required the ability for the simulated tissue to conduct thermal energy, to a level commensurate with tissue coaptation. For the purposes of development the Ligasure vessel sealing system manufactured by Medtronic was tested. The Valley lab system is a bipolar apparatus for sealing vascularised tissue. Despite the high coaptive pressure simulated in the model the mesh required a conductive material interspaced between the two jaws of the Ligasure. For this, the intermediary space between the greater curvature and thickened "omentum" was sprayed with water just prior to simulator use. The melted mesh formed a seal which was readily dividable using the built-in blade of the Ligasure.

The ability of the trainee to staple through the stomach in a similar manner to the authentic tactile feedback of a bariatric resection procedure was paramount. The thickness of the stomach required multiple refinements to allow the stapler to pass both the anterior and posterior walls, clamp, staple and cut adequately without being so thin as to become translucent or spontaneously rupture. For the purposes of the model the Medtronic Endo GIA Reinforced linear cutting device with tri-staple technology was used with preloaded buttress material. Black reloads were used for the entirety of the laparoscopic sleeve gastrectomy with variable staple heights of 4.0mm, 4.5mm and 5.0mm within the stepped cartridge.

A third essential component of the simulator required the ability to suture through an opened gastric pouch, as performed in a Roux-en-Y gastric bypass in the bariatric setting. For this the material needed to be pliable enough to allow passage of the needle and suture but not so thin as to tear through when the suture was pulled with a grasper through the tissue. An optimal thickness of 2.5mm not only allowed this to occur without the suture being pulled away from the swage of the needle but also mimics the common thickness of a stomach wall during a primary gastric procedure.

Results

Box trainer setup and after-market modifications

Each box trainer was modified to allow simulated passage of a gastric calibration device. An aperture was drilled out of the superior aspect of the plastic box of approximately 40mm. Subsequently a piece of plastic hose piping was passed caudally; given its relative stiffness it did not need further securing to the box itself.

The esophageal structure was strapped to the pipe using an elastic band. Next, the mesh omentum was secured up to the walls of the box trainer using Velcro hook tape which was circumferentially placed within the box trainer. The Velcro attached well to the omental mesh which allowed adequate tension for laparoscopic graspers to pull on; if the omentum became detached peripherally it could readily be reattached laparoscopically.

To mimic most bariatric procedures, the lid of the box trainer was placed with black neoprene foam of 3-4mm thickness and four defects created for each of the 5-15mm ports. Gas insufflation is not necessary in this model. Various laparoscopic instruments were provided including graspers, scissors, needle holders, a 10mm 30 degree laparoscope with optional arm rest and a Ligasure vessel sealing system. The laparoscopic stack was placed as per the usual surgical optical setup.

The training simulator was individually configured to replicate the three-major bariatric surgical procedures as described below:

Laparoscopically-placed adjustable gastric band

The placement of a gastric band firstly requires the trainee to create an aperture in pars flaccida, adjacent to the gastro-esophageal junction (Figure 2) and the ability to pass a blunt-nosed grasper behind the fundus to the Angle of His. Following this, a gastric band can be passed through a 15mm port into the abdomen. The band can then be placed around the superior aspect of the stomach with the option of having an "anaesthetist" pass a calibration balloon filled to the requisite volume for the purposes of accurate placement and tightness. The model also allowed for the creation of a gastro-gastric tunnel with braided sutures securing its placement at the fundus.

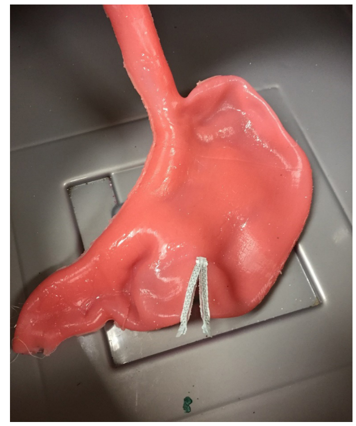

Figure 2: Stomach model with esophago-gastric junction demonstrated.

After the procedure, the trainee was encouraged to remove the model from the box trainer and examine their placement, which was also assessed by the examiner.

Laparoscopic Sleeve Gastrectomy

The model allows for resection of the omentum from the greater curvature using the bipolar vessel sealing system. The omental mesh falls to the base of the box trainer, over an optional pancreatic "mound" within the lesser sac. After passage of the calibration device, staple resection of the stomach utilising 60mm black reload cartridges along the length of the greater curvature can be performed as seen in Figure 3. The resected stomach is placed in the inferior aspect of the box whilst the trainee completes an omentopexy if they so choose. The mesh and silicon allows passage of either monofilament or braided suture types in performing the omentopexy without tearing through either material provided the trainee takes adequate tissue on either side. After the sleeve gastrectomy is performed the trainee and examiner can remove the sleeve and resected stomach to inspect the staple line angle, adequacy of incisural width and distance from the gastro-esophageal junction.

Figure 3: Single staple firing into resectable bi-layer stomach.

Laparoscopic Roux-en-Y Gastric bypass

Whilst the small bowel components of the Roux-en-Y gastric bypass have not been incorporated in this model, the initial aspects of gastric pouch creation over a calibration device, creation of aperture in pouch and suturing to a short segment of silicone-mesh small bowel can be performed. For this, the setup of the gastric model within the laparoscopic box trainer is similar to the previous two procedures. A defect is created in the lesser omentum, allowing passage of the linear cutting stapler. After the first firing the calibration device is passed requiring the trainee to communicate effectively with the "anaesthetist" to ensure adequate placement. Subsequently the linear stapling device cries used to create the gastric pouch. The resected stomach remains within the box trainer. An aperture is created, most easily with scissors. A short segment of simulated small bowel with pre-formed aperture is passed into the box trainer via a 12mm port. Given the relative stiffness of the small bowel model, the bowel does not need further fixation to surrounding structures to allow simulation of the sutured gastro0jejunal anastomosis. An anterior and posterior layer can be created using monofilament or braided suture material. After this anastomosis is completed the trainee is able to remove the specimen from the box trainer, examine the adequacy of the pouch and anastomosis, check patency and perform a leak test using dyed water.

Discussion

The necessity for use of simulation as an adjunct in surgical training has become more evident as working hours and training time has steadily decreased over the past decades. This educational void is most pronounced in smaller subspecialties such as bariatric surgery, whereby most of the work is performed in the private sector with limited trainee exposure. The validity of artificial models as a simulation for education and subsequent assessment algorithms has been shown in similar subspecialties, using the established principles of experimental design, validation and reliable assessment [3].

The advantages of models similar to the one described include - the lack of requirement for permission to use animal products or human cadavers, sterility of artificial tissue (silicone, rubber and mesh) in a relatively clean environment, as well as the ready-access for trainees in comparison to human tissue.

By far the most compelling rationale for a surgical simulator is its intended positive effect upon quality patient care. Patients are no longer tolerating being "practiced" upon, particularly for procedures the surgeon is unfamiliar with in training. The readily reproducible nature of the simulated model will allow for development of a bariatric surgical curriculum based around the model. In addition it has the potential to be utilised for assessment purposes, both in trainees as well as a practical modicum of competency in fellowed surgeons. This method is superior to time-based competency or purely by case volume, both of which are poor surrogate markers of competence. Criteria for "good" assessment as defined by a 2010 Ottawa conference include validity, reproducibility, equivalence, feasibility, acceptability, educational and catalytic effects [4]. The correlation between bench test technical evaluation of surgical skill with operating room performance assessments have been validated previously [5]. Such technical skills may also correlate with non-technical performance in some settings [6].

There are some limitations to the described model. The model stomach shape with its nuances and specific thickness was developed over several months with multiple transitions to incorporate silicone-impregnated mesh for the omentum. The box trainer is available in many large surgical simulation centres but infrequently found outside of these. Whilst it is a low cost simulator it is not without cost and access to such simulators would likely be outside of normal hospital hours, with the added requirement of access to a laparoscopic stack for training purposes.

There is great potential for further development with this model, particularly for more complex procedures such as the *Roux-en-Y* gastric bypass. The combination of the advantages of the stomach model presented with existing pliable small bowel models would possibly allow for a full-scale artificial model for a gastric bypass procedure with applications outside of bariatrics, particularly in oncological surgery.

Conclusion

Incorporation of a novel gastrectomy model into a bariatric surgical training framework has great merits of being reproducible and readily assessable for competency-based training within laparoscopic surgery. This should be utilised in the context of a validated curriculum for common bariatric surgical procedures, such as sleeve gastrectomy, gastric bypass and gastric band placement. Further development of practical aspects of the model, particularly for gastric bypass, would ensure upper gastro-intestinal surgery trainees are exposed to a baseline of practical techniques prior to undertaking each of these procedures. The predicted follow-on effects of improved patient safety has yet to be quantified but is a fertile area for future educational research.

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