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Characterising '*near miss*' events in complex laparoscopic surgery through video analysis

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Preliminary data from error analyses in bariatric surgery, in part reported in the present manuscript have been presented at the 19th World Congress of the International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO), Montreal 26–30 August 2014, and have been published in abstract form in *Obesity Surgery* 2014;24:1187. Event data obtained during prior studies, in part been reported in the present manuscript, have been presented at the 2013 ASMBS Obesity Week, Atlanta, Georgia, 13–15 November 2013.

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ABSTRACT

Background Root cause analyses of surgical complications are of high importance to ensure surgical quality, but specific details on technical causes often remain unclear. Identifying subclinical intraoperative incidents attributable to technical errors is essential for developing rescue mechanisms to prevent adverse outcomes.

Objective Descriptive study to characterise intraoperative technical error-event patterns in successful laparoscopic procedures.

Methods Events (injuries) identified during prior blinded analyses of 54 unedited recordings of bariatric laparoscopic procedures were subjected to a secondary review to determine the presumed underlying error mechanism. The recordings were obtained from one university-based bariatric collaborative programme, and represented consultant, fellow and shared trainee cases.

Results Sixty-six events were identified in 38 recordings, while 16 videos showed no events. In 25 (66%) of the videos that showed events, additional measures such as haemostasis or suture repair were required. Common identified events were minor bleeding (n=39, 59%), thermal injury to non-target tissue (n=7, 11%), serosal tears (n=6, 9%). Common error mechanisms were 'inadequate use of force/distance (too much)' (n=20, 30%) and 'inadequate visualisation' during grasping/dissecting (n=6, 9%), 'inadequate use of force/distance (too much)' using an energy device (n=6, 9%), or during suturing (n=6, 9%). All events were recognised intraoperatively.

Conclusions Analysis of successful operations allowed the identification of numerous error-event sequences. Reviewing injury mechanisms can enhance surgeons' understanding of relevant errors. This error awareness may aid surgeons in preparing for cases, help avoid errors and mitigate their consequences. Thus, this approach may impact future surgical education and quality initiatives aimed at reducing surgical risks.

INTRODUCTION

Numerous reports have explored the incidence of adverse outcomes and errors in healthcare. These reports provided valuable information on the root causes of adverse outcomes and indicated that in surgery, the majority of errors occurred within the operating room (OR) and that many of these errors can be considered technical in nature.[1 2] Although the knowledge gained from these retrospective studies is valuable, information on errors that did not cause a visible complication is lacking. These 'near misses' (ie, situations that had the potential to result in an injury or adverse outcome but failed to do so due to chance or through appropriate countermeasures)[3] may not be captured by retrospective reviews of archived charts or malpractice claims, especially if the underlying cause is an intraoperative technical error, but are of high importance since they allow protective measures to be taken to avoid future adverse events before a clinically relevant injury manifests.[4]

The nature of laparoscopy, which requires the transmission of an intraoperative picture to a screen, has enabled the thorough postoperative procedure analysis through video review. Sarker and colleagues (2005), for example, explored technical errors in laparoscopic cholecystectomy procedures performed by expert surgeons.[5] Following their analysis, the authors devised a hypothetical model of 'fluctuations of surgical errors' during operative cases. This model was based on the notion that minor errors occur throughout all cases. This 'background technical error rate' was supported by the finding that even experts committed errors during routine cases, likely as a consequence of human nature and complexity of psychomotor skills required for

laparoscopic surgery.[5] Further studies have supported this hypothesis documenting varying error rates depending on the procedure and level of training of the operating surgeon.[6–8] As a result, the concept of an error-focused training approach as a means to both reduce error and enhance error recovery through targeted training has been proposed.[9–11] This approach could benefit both trainees and practicing surgeons since a recent analysis of surgical skill and patient outcomes in bariatric surgery revealed a significant correlation between surgeon skill and patient outcome, underlining the importance of optimised technical competence at all levels of surgical training.[12]

In the case of trainees, it is acknowledged that they will invariably commit numerous mistakes and that this could be considered a valuable source of knowledge for experiential learning, provided there is a system facilitating identification, analysis and constructive feedback.[13 14] Therefore, the first step towards error reduction and mitigation appears to be to foster an understanding of common errors and to create awareness of potential injury mechanisms by acknowledging error-event patterns.[11] The objective of the present study, therefore, was to characterise common intraoperative error-event mechanisms in routine complex laparoscopic procedures.

METHODS

Study design

This study was conducted as a secondary review of data, involving the retrospective review of procedural video clips.

Error analysis

All error analyses were conducted using the Generic Error Rating Tool (GERT).[8] The GERT represents a simplified step-independent framework that can be used to categorise technical errors in laparoscopic surgery.[8]

Definitions

In the present study, 'errors' represent the smallest unit of deviation from the intended operative course. Based on the GERT framework, errors could be described by the type of deviation 'inadequate use of force or distance (too much or too little)', 'wrong orientation of instrument or dissection plane' and 'inadequate visualisation' as well as by the task during which they were observed (eg, during abdominal access, use of retraction, use of energy devices, grasping and dissection, cutting, transection and stapling, clipping, suturing, suctioning).[8] The events in the present study correspond to 'minor events' as detailed in prior classifications,[15] potentially requiring actions but without affecting the overall course of the operation. The term 'error mechanism' in the present study refers to the error that contributed to the analysed event.

Study sample

Ethics boards have approved several research projects involving error analysis of procedural videos, which have been conducted in a second to second analysis by a bariatric surgeon, in a blinded fashion. The video analysis software (Studiocode V.5, Sportstec, Warriewood, Australia) used allows for time-stamped marking of defined instances (in our case errors and events) on a video-independent timeline. Within the analysis software, the GERT analysis was combined with the procedural step classification of the hierarchical task analysis underlying the Bariatric Objective Structured Assessment of Technical Skill tool to enable an accurate association of an error within a procedural step.[16] Video sequences of the time-stamped events had been extracted with the datasets. These sequences included the marked event together with the preceding time frame that included any marked errors. The original videos had been deleted on completion of the primary analyses, retaining only the anonymised video segments which were the basis for the present secondary analysis.

For the present study, all datasets of laparoscopic Roux-en-Y gastric bypass (LRYGB) procedures (n=54) reflecting 78 h of operating time, were assessed to identify those that had been marked with intraoperative events. The primary video pool of the dataset represented unedited routine cases from one university based multisite bariatric collaborative programme, and was a mix of 'single bariatric surgeon only' (n=19) and 'shared trainee' (n=35) cases. Shared cases involved more than one surgeon acting as the primary surgeon for parts of the procedure, with any combination of a specialist bariatric surgeon, advanced minimally invasive surgery fellow, or trainee participating.

Determining event mechanisms

The aforementioned video segments were re-reviewed by the original rater, and reviewed by a second rater, a fellowship-trained practicing bariatric surgeon and educator (blinded to surgeon identity and training level). Both raters independently assessed the video segments describing the presumed event and stating which error they felt had caused the observed event. Following the methodology detailed by Regenbogen *et al*,[17] descriptions of events and underlying error mechanisms were compared between both raters. In cases of disagreement, the two raters discussed until a consensus was achieved. Inter-rater agreement was calculated based on the results of the initial independent review.

Statistical analysis

This was a descriptive study with the variable of interest being error-event sequences. Inter-rater reliability was assessed using Cohen's κ. All analyses were performed using SPSS V.20 statistical software (IBM).

RESULTS

Events

Sixty-six events were identified in 38 of the 54 videos. Sixteen videos showed no events. In 25 (66%) procedures that contained at least one event, a rectification intervention (table 1) was required. The median rectification duration was 111 s (range 6–820 s).

Inter-rater agreement

Inter-rater reliability for event description was excellent (Cohen's $\kappa=0.977$, $p<0.001$, 95% CI 0.932 to 1) and inter-rater reliability for the underlying error mechanism was substantial (Cohen's $\kappa=0.79$, $p<0.001$, 95% CI 0.685 to 0.897).[18]

Consensus

Consensus discussion was required for one event: rater 1 assessed the injury as a haematoma of the bowel wall, whereas rater 2 described the injury as a serosa tear. After a review of the clip and discussion, both raters agreed that the best description of the injury was a serosa tear (with secondary bleeding). With regards to error mechanisms, the raters disagreed in 12 instances. In four of these, the disagreement was with regards to error task-group (eg, grasping vs use of energy depending on which instrument was presumed to have caused the injury); in eight, the presumed underlying error mode differed (eg, too much vs too little force).

Events

The 66 observed events were instances of haematoma and minor bleeding (n=39), thermal injury to non-target tissue (n=7), serosa tear (n=6), devascularisation of a small bowel segment after jejunal transection (n=5), entangled or broken sutures (n=4), torn falciform ligament (n=2), perforated mesentery (n=1), staple line failure (n=1) and non-target tissue caught in staple line (n=1).

Table 1 Examples of rectification measures

Bleeding	To stop bleeding, surgeons could apply clips to the tissue to occlude the bleeding vessel or apply electrocautery to coagulate it
Serosa tears (tear in the outer layer of the bowel wall)	To reinforce the damaged bowel wall, surgeons can oversew the injury
Devascularised bowel edges (poor blood supply to resection boarders)	In the setting of visibly reduced blood flow (ischaemia) viability of the tissue may be compromised. If clearly compromised, the under-perfused bowel segment needs to be removed. This resection usually involves a few centimetres of bowel and is carried up to the point where the bowel wall appears healthy and well perfused

Error mechanisms

The most commonly observed error mechanisms in the present sample were those due to 'use of inadequate force or distance (too much)' when grasping/dissecting (n=20) which could be seen to lead to avulsion or tearing of tissue which could lead to bleeding or serosal injuries, 'inadequate visualisation' during grasping/dissecting (n=6) commonly associated with injury to vessels in the not visualised deeper tissue layers, 'inadequate use of force or distance (too much)' when suturing (n=6) resulting in either overshooting and inadvertent minor vessel injury beyond the target or ripping of sutures requiring a new-start, 'inadequate use of force or distance (too much)' or 'wrong orientation of instrument or dissection plane' when using an energy device (n=6 and n=5, respectively) often leading to thermal injury of non-target tissue, while 'inadequate visualisation' when using an energy device (n=4) mostly resulted in bleeding. 'Wrong orientation of the instrument or dissection plane' during stapling/transecting (n=5) was commonly seen to lead to devascularisation of a segment of the transected small bowel. Less frequent were errors due to 'wrong orientation of instrument' during suturing (n=4), or during clipping (n=1), 'inadequate use of force or distance (too much)' while stapling/transecting (n=3) or clipping (n=1), 'inadequate use of force or distance (too little)' while grasping (n=2) or stapling/transecting (n=1), 'inadequate visualisation' during stapling/transecting (n=1), and suturing (n=1).

Enactors and procedure step

The majority of events in the present sample were caused by bariatric surgeons (n=41), whereas a fewer number were caused by fellows (n=15) and trainees (n=10). An overview of the main operative steps of the LRYGB procedure is shown in table 2. The events were most frequently observed during the operative step of gastric pouch creation (n=30), with the majority (n=18) of these occurring during the steps related to dissecting the lesser curve and creating a posterior gastric tunnel in preparation for transverse gastric division. The steps relating to creating the gastrojejunostomy (n=11), measuring the biliopancreatic limb (n=11) and creating the jejunojejunostomy (n=5) accounted for the majority of remaining events. Other steps combined, such as adhesiolysis, splitting omentum, positioning the Roux-limb, mesenteric closure, accounted only for nine events; however, some of these steps were not performed in all procedures. No events were observed during the introduction of trocars and set-up phase, or during the closure phase of the procedure.

DISCUSSION

Although surgeons strive to consistently adhere to sound surgical principles and wish to avoid technical

Table 2 Overview of operative steps of laparoscopic Roux-en-Y gastric bypass

Steps	Description
Splitting omentum	The omentum may be divided to facilitate tensionless positioning of the bowel during the creation of the gastrojejunal anastomosis
Measuring biliopancreatic limb	Starting at the ligament of Treitz the small bowel is measured distally to a length of approximately 40–60 cm and divided
Creating the jejunojejunostomy	Following the division of the bowel, the alimentary limb is measured out (75–150 cm). The biliopancreatic limb is reconnected to the alimentary limb at this measured point. The reconnection of the two bowel segments is termed the jejunojejunostomy
Gastric pouch creation	The stomach is partially divided in a horizontal angle at the level of the lesser curve. From this division line, the stomach is then transected in a vertical fashion up to the angle of His to result in a small residual stomach pouch
Gastrojejunostomy creation	The new stomach pouch is reconnected to the bowel (alimentary limb/Roux-limb). This new connection is termed gastrojejunostomy.
Mesenteric closure	The defect between the two transected mesentery edges is sutured closed to prevent internal herniation of bowel

The steps described can be performed in a varying order and represent only a basic overview of the procedure. The steps of measuring biliopancreatic limb, jejunojejunostomy, gastrojejunostomy or pouch creation can be further subdivided into several smaller steps as detailed in a prior hierarchical task analysis.[16]

errors, the present study demonstrated that numerous error-event sequences may still be identified in successful routine operations since human error can never be fully avoided. The most common injuries were due to basic surgical tasks and were predominantly enacted by trained surgeons. The present analysis can thus inform surgeons and trainees alike about potential hazards and remind surgeons that even the most basic task execution may have an adverse consequence.

Numerous studies have been conducted to identify factors that may contribute to adverse patient outcome.[1 12 17 19–22] These studies focus on patient outcome as a function of an identified and diagnosed complication. Instances where a potential hazard was recognised and mitigated remain outside the scope of these reports leading to a significant loss of data having clinical, educational and economical relevance. Subsequently, a few prospective studies have been conducted with the aim to better understand these 'near miss' situations in surgery, either through direct observation[23] or by applying video recording techniques.[24 25] Hu *et al*[24] and de Leval *et al*[23] applied a comprehensive approach to analysing perioperative events and demonstrated that events, even those that could potentially endanger patient safety, are very common. Furthermore, a cumulative effect of even minor events was noted to adversely impact patient outcome.[23] These studies, however, did not primarily assess the impact of factors associated with technical skills. The present work focused on technical aspects of surgical performance. As technical errors have been identified as a major source of injury resulting in disability,[17 20] knowledge about intraoperative risks and appropriate rescue mechanisms may have a significant impact on patient safety and clinical outcomes. For example, common technical manoeuvres such as blunt, blind dissection of the lesser curve of the stomach during pouch creation were identified as a leading cause of bleeding. Although all episodes of bleeding were minor and managed promptly, additional efforts were frequently required to achieve adequate control. Where one surgeon may easily control bleeding, another may make inappropriate decisions leading to a cascade of adverse events that could result in an adverse outcome. Therefore, by acknowledging the hazard in the step, surgeons can mentally prepare and assign cognitive resources for potential error recovery mechanisms.[14] Similarly, by better understanding the origin of events, specific manoeuvres can be avoided altogether. For example, missed enterotomies have been identified as a significant source of adverse patient outcome leading to lawsuits in bariatric surgery.[20] By acknowledging the fact that a serosal tear, as a precursor to an enterotomy, may be the result of inadequate application of force during grasping the bowel, surgeons should be more vigilant and wary of any handling of bowel off-screen as potential injuries may be missed. Although most bariatric surgeons are likely to be aware of the risk of handling bowel with too much force, the risk of too little force may be underestimated as a recent expert consensus revealed.[26] It must be noted, that not all events identified in the present sample should be classified as 'near misses' as they are unlikely to endanger patient safety. Incidents such as breaking or entangling sutures, torn falciform ligament and catching of non-target tissue in staple lines would likely only disrupt the flow of the procedure and may require extra efforts to rectify. Furthermore, in the current sample the majority of required rectifications were only minimal as was reflected by the short duration of these interventions. These events could be classified as 'minor events',[15] rather than 'near misses'. Similar results to the present study were found in previous work, although the distribution of error mechanisms differed.[8] In addition, the video sample for the present study also included recordings from several different primary surgeons and hospital sites, thus generalising the findings to include discreet variations in surgical techniques.

Furthermore, although the analysis was focused solely on technical errors, the role of knowledge and judgement deserves consideration. Frequently, a technical error may be the starting point of an error-event-complication cascade, but whether an event is recognised, interpreted correctly and, subsequently, managed appropriately lies in the domain of knowledge and judgement. In addition, several errors, such as applying a stapler in the wrong orientation across the bowel, although technical in

execution, are commonly the consequence of misinterpretation of anatomy or lack of procedure knowledge.

All surgeons are prone to committing errors, and numerous studies have highlighted that errors are frequent;[5–8 27] subsequently, all surgeons have the potential to cause an inadvertent injury. In the present study, the majority of events were caused by practicing surgeons, which is likely due to the sample of videos used for analysis. Nineteen of the original videos were single surgeon cases; in addition, in shared procedures, trainees would infrequently have performed two of the three steps with the most events (pouch creation and gastrojejunostomy creation). These two steps are more frequently performed by consultant level surgeons or fellows. This is in part due to the prevailing belief that the steps are more complex and that events may be harder to rectify. The current data do support the notion, that these steps may possibly be considered more difficult. Further objective analysis of error distributions using error-event ratios in combination with procedural step analysis is currently underway to document procedure step complexity in LRYGB.

The OR represents an essential environment for learning which cannot be fully replaced. In the context of experiential learning, the opportunity to learn from errors represents a valuable source of information that can be used to teach surgical decision making, risk management and error recovery mechanisms. But it may not be necessary for the individual to learn from mistakes made by themselves, it may also be sufficient to learn from exemplar errors. Subsequently, recent training concepts have evolved around topics of error training, aiming at instructing error recognition, error rescue and risk management.[9–11 14] Although the specific error mechanisms and events identified in the present study may not be generalisable to other surgical settings using variations in surgical technique, educators can develop a knowledge base of common technical errors relevant to their specific setting by conducting video reviews of routine cases. This knowledge could subsequently be used to design targeted technical training interventions to address the most common consequential errors. Edited video segments can be used as educational material highlighting frequent injury mechanisms, which may aid trainees in understanding why specific manoeuvres are undesirable. By reducing errors that result in events, procedure duration and costs may be reduced since event rectification may require additional materials and time efforts depending on the nature of the injury. Error preparedness may thus help in reducing overall costs, a topic that will need to be explored in future research.

Limitations

The current study has several limitations. First, the video clips used represented a convenience sample and, therefore, the event rate of 70% cannot be generalised. Potentially, in samples that were not selected by the primary surgeons, event rates could well be higher However, the interest was not in determining the event frequencies. It was rather to characterise error-event mechanisms and to demonstrate feasibility of the method. Due to the heterogeneity of the original study sample total error counts were not a focus of this study, and all errors that had not resulted in an event (inconsequential) were not part of the present study. Second, since participation in the research studies was voluntary, contributing surgeons were free to select which videos to submit from their personal educational archives. This may have resulted in surgeons selecting only cases deemed to show good performance, which may be the reason why more significant injuries were not observed. Rare but remarkable and dangerous events have been described in the context of case reports.[28 29] However, less critical events have largely not been the topic of publications and these seemingly 'routine' events that can commonly occur should also be known by surgeons and trainees. Third, no information on patient outcome was available; consequently, the relevance of the identified events for patient outcome could not be ascertained. Nevertheless, due to the nature of some of these injuries and the potential for harm if left unrectified, several of these minor events still qualify as 'near misses' warranting investigation. A prospective observational study is currently underway to determine the relevance of intraoperative errors and events on patient outcome, as well as to assess the relationship between technical errors and other measures such as nontechnical performance and environmental factors. Last, due to the anonymous retrospective nature of the data, specific feedback was not afforded to the individual surgeons. The value of routine video recording in healthcare has recently been emphasised;[30] the current study highlights how even seemingly uncomplicated cases can be a useful source of education, and that timely feedback may be valuable to surgeons of all levels of training.

CONCLUSION

Error awareness is essential in daily surgical practice and surgical training. The current study highlights the benefits of detailed video analysis to create a database of common injury mechanisms and video clip repository that can be used in tailoring future training interventions. In addition, practicing surgeons should be encouraged to review their operations as even successful procedures can be a valuable source of learning prompting self-reflection. Understanding the casual relationship between minor errors and intraoperative events is essential for the development of effective error rescue mechanisms for future cases.

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Contributors EMB was involved in conception and design of the study, acquisition, analysis and interpretation of the data, drafting of the manuscript, and statistical analysis. LEG was

involved in the design of analysis windows for the primary video reviews, revision of the manuscript and technical support throughout the primary data analysis phase. TPG was involved in the design of the study, acquisition and interpretation of the data, critical revision of the manuscript, obtaining funding, and supervision throughout the study.

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Data sharing statement The data table including error mechanisms, event descriptions and consensus items can be obtained from the corresponding author on request.

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