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SAGES expert Delphi consensus: critical factors for safe surgical practice in laparoscopic cholecystectomy

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Abstract
Background Although it has been 25 years since the introduction of laparoscopy to cholecystectomy, outcomes remain largely unchanged, with rates of bile duct injury higher in the modern age than in the era of open surgery. The SAGES Safe Cholecystectomy Task Force (SCTF) initiative seeks to encourage a culture of safety in laparoscopic cholecystectomy (LC) and reduce biliary injury. An expert consensus study was conducted to identify interventions thought to be most effective in pursuit of this goal.
Methods An initial list of items for safer practice in LC was identified by the SCTF through a nominal group technique (NGT) process. These were put forward to 407 SAGES committee members in two-stage electronically distributed Delphi surveys. Consensus was achieved if at least 80 % of respondents ranked an item as 4 or 5 on a Likert scale of importance (1–5). Additionally, respondents ranked five top areas of importance for the following domains: training, assessment, and research.
Results Thirty-nine initial items were identified through NGT. Response rates for each Delphi round were 40.2 and 34 %, respectively. Final consensus was achieved on 15 items, the majority of which related to non-technical factors in LC. Key domains for training, assessment, and research were identified. Critical view of safety was deemed most important for overall safety, as well as training and assessment of LC. Intraoperative cholangiography was identified as an additional priority area for future research.
Conclusions Consensus items to progress surgical practice, training, assessment, and research have been identified, to promote safe practice and improve patient outcomes in LC.

Keywords Cholecystectomy · Patient safety · Consensus · Expert

Introduced in the late 1980s [1, 2], the laparoscopic approach to cholecystectomy has revolutionised the

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surgeon's approach to the procedure. Laparoscopy has been shown to offer improved cosmesis, reduced length of inhospital stay, and more rapid convalescence compared with open cholecystectomy [3, 4]. Over 700,000 cholecystectomies are now performed annually in the USA alone, the vast majority laparoscopically [5].

The rapid uptake of laparoscopy, however, has not been without cost. Despite studies demonstrating equivalent morbidity and mortality rates for laparoscopic and open approaches [3, 6], early studies suggested that this was tempered by the fact that a reduction in minor complications such as wound infection was, in fact, offset by an increase in major bile duct injury (BDI) complications [7]. The Southern Surgeons' Club's 1991 analysis of 1518 laparoscopic cholecystectomies (LCs) reported a BDI rate of 0.5 % [7], up to five times higher than the previously cited rates of 0.1–0.2 % for open cholecystectomy [8, 9].

Regrettably, this higher rate of BDI has persisted in the modern era of LC. Recent studies drawing upon large-scale or national database cohorts have reported rates of BDI ranging from 0.2 to 1.1 % [10–13]. The severe nature of BDI following LC is reflected in the greatly increased risk of serious morbidity, mortality, and length of stay [14], in addition to reduced quality of life [15] and long-term survival [16, 17]. Furthermore, the economic impact of BDI must also be considered. Analyses of litigation claims demonstrate BDI to be the cause of the majority of lawsuits following LC, resulting in average settlements of up to $500,000 USD [18–20]. One estimate places the annual cost of litigation related to BDI in excess of $1 billion USD in the USA alone [21].

Efforts to improve safety in LC have greatly increased the body of knowledge across nearly all domains of care relevant to cholecystectomy. These include timing of the procedure and patient selection [22], to training and assessment of surgeons performing LC [23]. Intraoperative processes to ensure safety of the procedure have been championed, such as photographic documentation [24] of the "critical view of safety" first described by Strasberg and colleagues almost 20 years ago [25], and the use of intraoperative cholangiography [26].

Despite this, many of the above-described interventions have failed to achieve significant uptake, and outcomes have remained largely unchanged. BDI rates remain significantly higher now than a quarter of a century ago in the era of open surgery [27]. It is likely that a new, consensus-driven approach is needed, if change is to be achieved.

The Society of American Gastrointestinal Endoscopic Surgeons (SAGES) has launched a new initiative in this context, to improve safety in laparoscopic cholecystectomy (LC), spearheaded by the Safe Cholecystectomy Task Force (SCTF). This group's objective is to encourage and catalyze a universal culture of safety for cholecystectomy with the goal that its adoption would result in a decrease in the incidence of BDI. This study, representing the first output from the Task Force, sought to identify the future directions for process improvement, training and research with the greatest potential to improve outcomes in LC, through expert consensus.

Methods

Initiation of the SAGES Safe Cholecystectomy Task Force

The current leadership of SAGES has placed efforts to enhance patient safety and improve surgical outcomes at the center of the society's strategy. The improvement of safety in LC has been given a central role, directed in part by a group of practicing laparoscopic surgeons with an interest in patient safety, the SCTF. To ensure that the interests of the broader surgical community were represented and to create a "road map" for this initiative, a two-phase consensus process, consisting of nominal group and Delphi techniques, was used.

Nominal group technique

In April 2014, the SAGES SCTF, a group of expert gastrointestinal surgeons with an interest in surgical education and patient safety, convened a meeting to generate an initial list of factors to improve safe practice in LC. The nominal group technique (NGT) was applied. NGT is a highly structured process of idea generation, with resulting ideas aggregated according to importance and relevance [28]. It allows ideas to be generated by individuals without the risk of decision being biased by choices or opinions of other group members, before combining ideas with the rest of the group to be agreed on by a majority.

Participants were asked to suggest critical safety factors for LC across three domains: operative (technical), perioperative, and non-technical factors. Ideas across all participants were collated, with participants then asked to each select and rank factors in order of their perceived importance. A rank-ordered list was presented and finalized through the combining of similar or redundant items, and exclusion of irrelevant ones, as agreed by the group majority.

Delphi consensus

The list of items generated by NGT was then subjected to a Delphi process to achieve consensus. The Delphi process is an iterative consensus technique which provides anonymous feedback to participants in each round about the choices made by their peers in previous rounds. In this manner, individuals are free to change their opinion based

on the group's influence, but without the risk of disproportionate bias from any particularly senior or dominant individuals, as might otherwise result from live discussion [29].

All SAGES committee members were invited to participate in the two-round Delphi consensus via an e-mailed online survey, with explicit instructions to participate only if they performed LC as part of their current independent surgical practice. Participants completed a demographic questionnaire, before ranking each NGT item on a Likert scale of 1 (not at all important) to 5 (very important) for their importance to safe practice in LC. Free-text space was given to suggest additional items, if necessary. In addition, participants were asked to name the five most important NGT-determined items in rank order of perceived relevance to (1) resident education, (2) performance assessment, and (3) future scientific research for safe practice in LC. A reminder was sent at 2 weeks, and the first-round survey closed at 4 weeks following the initial invitation.

Results (mean ± SD of each item) were circulated as part of the second round survey 2 weeks later, in which participants re-ranked items in a similar manner. Again, an electronic reminder was circulated at 2 weeks, and the Delphi process closed at 4 weeks following initial invitation.

Data analysis

Analysis of the second round Delphi results was conducted in Microsoft Excel 2011 (Microsoft Corp, Redmond, WA). For the primary question—determining factors critical to safe practice of LC—consensus was reached if at least 80 % of respondents ranked an item as 4 or higher (on a Likert scale of 1–5). Each item was designated as relating to a technical, non-technical, or perioperative domain of care as determined during the initial NGT process. For responses to the secondary questions—naming the top five factors for education, assessment, and research, items were ranked in terms of number of times they were named as a top-five item; if two items achieved the same number of nominations, the final order was determined by higher mean ranking.

Results

Nominal group technique

Eleven surgeons (members of the SAGES SCTF) took part in the NGT. All were board-certified general surgeons and practiced primarily in academic centers (8/11), community hospital (1/11), private practice (1/11), no reply given (1/11), with a median 22 years of independent practice (range 6–60 years). Most indicated an annual volume of 50–100 LCs [5/11; also 100–200 LC/year (3/11), 20–50 LC/year (2/11), 10–20/year (1/11)], 8 of 11 had completed over 1,000 previous LCs 2 of 11 500–1,000 LCs, and 1 of 11 300–500 LCs.

Through the NGT process, a total of 39 factors were identified and deemed relevant to safe practice in LC (Table 1). These were included in the subsequent Delphi process.

Delphi consensus

Demographic data

Four hundred and seven SAGES committee members received an invitation to complete each round of the Delphi consensus survey (SurveyMonkey, Palo Alto, CA).

The first-round survey was completed by 164 respondents (40.2 % response rate), with the second round completed by 139 respondents (34 %). Respondents referred to themselves as general surgeons (78/164, 47.6 %), upper gastrointestinal surgeons (35/164, 21.3 %), bariatric surgeons (31/164, 18.9 %), colorectal surgeons (7/164, 4.3 %), hepatobiliary surgeons (7/164, 4.3 %), pediatric surgeons (5/164, 3.1 %), and endocrine surgeons (1/164, 0.6 %). Approximately 90 % (148/164) possessed relevant board certification and had 12.4 ± 9.4 (mean ± SD) years of independent practice. One hundred and thirteen of 164 (68.9 %) respondents conducted a majority of their practice in a university-affiliated center, 34 of 164 (20.7 %) in a community teaching hospital, and 17 of 164 (10.4 %) in a community non-teaching hospital. Most had access to specialist services such as endoscopy (162/164, 98.8 %), endoscopic retrograde cholangiopancreatography (156/164, 95.1 %), endoscopic ultrasound (145/162, 88.4 %), and interventional radiology (151/164, 92.1 %). Only two respondents (1.2 %) reported access to none of the above.

Respondents were asked to indicate their surgical experience. The mode was 21–50 annual LCs (55/164, 33.5 %), with a total of 201–300 previously completed LCs (55/164, 33.5 %). One hundred and sixty of 164 (97.6 %) were comfortable performing and interpreting IOC. While 29 of 164 (17.7 %) performed IOC routinely (>90 % of cases), the mode (85/164, 51.8 %) performed IOC less than 10 % of the time. One hundred and ten of 164 (67.1 %) were comfortable performing transcystic laparoscopic common bile duct exploration (CBDE), and 59 of 164 (36.0 %) reported the ability to perform transcholedochal CBDE; 25 of 164 (27.4 %) did not perform CBDE. The mode annual volume was less than five CBDEs (92/164, 56.1 %).

Delphi consensus results

Twenty-six factors were identified by 80 % or greater of respondents as being "important" or "very important"

Table 1 Factors for safe practice in laparoscopic cholecystectomy identified through nominal group technique process

1. Establishing the critical view of safety	14. Timing of operation with reference to disease history	27. Appropriate use of energy devices by primary surgeon
2. Surgeon able to perform and interpret IOC	15. Anticipation of difficult case and appropriate management	28. Preoperative discussion of case with anesthesiologist
3. Recognize need for conversion or alternate procedure	16. Management of patient comorbidities	29. Decompression of tense gallbladder prior to dissection
4. Understanding of relevant anatomy	17. Operating room setup and availability of equipment	30. Hospital availability of IOC
5. Appropriate intraoperative retraction and exposure	18. Intraoperative "time-out" to confirm critical view of safety	31. Photographic documentation of critical view of safety
6. Preoperative patient workup	19. Maintained plane of dissection of gallbladder	32. Know when to refer to tertiary unit
7. Adequate experience of primary surgeon	20. Appropriate establishment of pneumoperitoneum and port placement	33. Patient positioning on operating table
8. Intraoperative team communication	21. Securing of cystic artery	34. Appropriate decision to proceed with operation
9. Knowing when to call for help	22. Recognize postoperative complications/deviations from expected postoperative course	35. Appropriate tissue handling
10. Prioritizing difficult procedures on the operating room schedule	23. Appropriate assistant skill level	36. Appropriate hemostasis
11. Start dissection of Calot's triangle high on gallbladder	24. Patient education	37. Team safety culture
12. Preoperative team briefing ("huddle")	25. Avoidance of injury of right hepatic artery	38. Good trainer–trainee communication
13. Securing of the cystic duct	26. Do not persist with dissection in setting of severe inflammation/fused hepatocystic triangle	39. Postoperative team debriefing

IOC intraoperative cholangiogram

through the first Delphi round (Appendix 1). Following the second Delphi round, final consensus was achieved on fifteen items (Table 2).

Across both rounds of the Delphi process, the same items were ranked at the top as the five most important factors to safe practice, with two major themes emerging. The first related to safe identification of biliary anatomy: (rank 1) establishing the critical view, (2) understanding of relevant anatomy, and (3) appropriate retraction/exposure. The second theme focused on surgical decision making: (4) knowing when to call for help and (5) recognizing the need for conversion or an alternate procedure (such as subtotal cholecystectomy).

Asked to identify factors relevant specifically to resident training for LC (Table 3, full results Appendix 2), experts identified the top five items as being (1) establishing the critical view, (2) understanding of relevant anatomy, (3) appropriate retraction and exposure, (4) correct approach to dissection of Calot's triangle from high on the gallbladder, and (5) knowing when to call for senior assistance.

For assessment (Table 3, full results Appendix 3), experts again included (1) establishing the critical view, and (2) understanding of anatomy, as well as (3) appropriate retraction and exposure, in addition to (4) surgeon ability to perform intraoperative cholangiography and (5) appropriate use of energy devices.

Finally, the most commonly identified topics for research (Table 3, full results Appendix 4) identified were as follows: (1) surgeon ability to perform intraoperative cholangiography, (2) establishing the critical view, (3) optimal timing of LC with reference to the disease history, (4) appropriate use of energy devices, and (5) how to recognize the need for conversion or alternate procedure.

Discussion

Twenty-five following the introduction of LC, bile duct injury remains a significant risk of this procedure. That such a serious complication may result from a very common procedure undertaken for benign disease, underlines the need for renewed initiative to improve safety in LC. It is estimated that 1,400–7,700 patients a year will suffer a major bile duct injury during LC [27]. The number is staggering if one considers that the vast majority of these patients come for an outpatient procedure and are expected to be back to their normal activities within 2 weeks or less.

This study presents the results of a structured Delphi consensus study, with participants drawn from the leading members of the world's largest society for laparoscopic surgery, SAGES. The resulting consensus list forms the

Table 2 Delphi consensus results for factors for safe practice in laparoscopic cholecystectomy, ordered according to importance as determined by final consensus results. Ratings given as mean ± SD

Critical factor	Delphi round 1			Delphi round 2		Item domain		
	Rating	% ratings 4 or 5	R1 rank	Rating	% ratings 4 or 5	Tech	Non-tech	Peri-op
Establishing the critical view of safety	4.86 ± 0.18	96.9	2	4.83 ± 0.16	99.3	×		
Understanding of relevant anatomy	4.92 ± 0.1	98.7	1	4.93 ± 0.13	98.6		×	
Appropriate intraoperative retraction and exposure	4.77 ± 0.21	98.7	4	4.67 ± 0.25	98.6	×		
Knowing when to call for help (e.g., senior colleague)	4.83 ± 0.17	98.8	3	4.64 ± 0.35	97.8		×	
Recognize need for conversion or alternate procedure	4.74 ± 0.28	96.9	5	4.55 ± 0.31	97.1		×	
Recognize postoperative complications/deviations from expected postoperative course	4.73 ± 0.27	96.2	6	4.57 ± 0.39	96.4			×
Adequate experience of primary surgeon	4.69 ± 0.23	99.4	7	4.31 ± 0.37	92.1		×	
Securing of the cystic duct	4.56 ± 0.35	95.0	11	4.39 ± 0.4	92.1	×		
Appropriate decision to proceed with operation	4.53 ± 0.46	93.8	14	4.32 ± 0.46	89.2		×	
Appropriate use of energy devices by surgeon	4.63 ± 0.36	95.0	9	4.32 ± 0.57	87.8	×		
Surgeon able to perform and interpret intraoperative cholangiography	4.56 ± 0.45	92.5	12	4.34 ± 0.53	87.8	×		
Appropriate tissue handling	4.55 ± 0.42	93.8	13	4.22 ± 0.45	87.8	×		
Appropriate hemostasis	4.56 ± 0.35	96.3	10	4.25 ± 0.48	87.1	×		
Avoidance of injury of right hepatic artery	4.67 ± 0.35	96.3	8	4.22 ± 0.55	82.7	×		
Start dissection of Calot's triangle high on gallbladder	4.39 ± 0.69	86.7	23	4.19 ± 0.76	80.6	×		

R1 rank overall item rank in first round of Delphi, *Tech* technical domain, *Non-tech* non-technical domain, *Periop* perioperative domain

cornerstone for what we hope will catalyze a renewed push to objectively define and standardize measures to ensure safe practice in LC. Consensus was reached on 15 final items, with a "top five" list of priorities additionally identified for the specific domains of residency training, assessment, and research.

Of the 15 consensus items, half of the top 10 consensus items related to non-technical skills; of the remainder, four related to technical items and one item to perioperative care. Thus, the consensus has reflected the evolution of surgery over the past few decades, which has seen a shift in the historical emphasis on technical ability, to incorporate a growing understanding of the importance of non-technical performance [30] and perioperative processes [31] for surgical outcomes.

The continued need to improve knowledge in this area is highlighted by the 2003 analysis of 252 bile duct injury cases [32] reported by Way and colleagues. In this study, the authors reported that in 97 % of cases, non-technical errors—predominantly relating to perceptual errors, in which the operator was led to make false assumptions regarding the position of the bile duct in relation to the anatomy at hand—were at the root cause of the injury. Many of their recommendations to avoid BDI are mirrored in the leading items identified by this consensus study, with the establishment of the critical view (Delphi consensus rank 1) and understanding the relevant anatomy (2), aided by adequate retraction and visualization (3), all crucial to correct identification of the cystic and common bile ducts.

Considering the areas of priority for implementing change for the next generation of laparoscopic surgeons, the results were similar for both training and assessment domains. While some items are already the subject of active research and educational interventions, such as the SAGES Fundamental Use of Surgical Energy (FUSE) program [33] to improve and assess the appropriate use of energy devices, many other areas remain unaddressed.

On the basis of this consensus study, future efforts must prioritize trainees' understanding of the critical view and it is formalized assessment. In addition to setting training goals, the exploration and development of valid and unobtrusive assessment tools is required. Routine photographic or video-based documentation of the CVS has been championed in some countries such as the Netherlands, where it has been endorsed by the Dutch Surgical Society [34] and is utilized there by the large majority of surgeons [35]. However, resource limitations, such as a lack of necessary equipment to facilitate image or video recording and linkage to medical records, may mean that such practice is more difficult to achieve on a broader international scale. Future efforts will require a pragmatic approach to introducing feasible and universally implementable interventions.

Table 3 Delphi consensus results to identify top five factors relevant to (A) training, (B) assessment, and (C) research for safe practice in laparoscopic cholecystectomy

	Delphi round 1			Delphi round 2		
	% responses	Mean rank	R1 rank	% responses	Mean rank	R2 rank
Factors relevant for training						
Establishing the critical view of safety	87.8	1.52 ± 0.92	1	92.0	1.59 ± 0.98	1
Understanding of relevant anatomy	35.8	3.11 ± 1.95	4	84.0	2.51 ± 1.48	2
Appropriate intraoperative retraction and exposure	58.8	2.57 ± 1.32	2	69.6	2.66 ± 1.09	3
Start dissection of Calot's triangle high on gallbladder	38.5	2.49 ± 0.9	3	52.0	2.97 ± 1.28	4
Knowing when to call for help (e.g., senior colleague	22.3	3.91 ± 1.4	8	38.4	4.04 ± 1.15	5
Factors relevant for assessment						
Establishing the critical view of safety	85.4	1.31 ± 0.6	1	92.0	1.24 ± 0.43	1
Understanding of relevant anatomy	31.1	2.83 ± 1.92	5	75.2	2.95 ± 1.6	2
Surgeon able to perform and interpret intraoperative cholangiography	48.0	2.56 ± 1.08	2	67.2	2.95 ± 1.52	3
Appropriate intraoperative retraction and exposure	39.9	2.8 ± 1.54	3	59.2	2.96 ± 1.16	4
Appropriate use of energy devices by surgeon	31.8	3.47 ± 1.3	4	33.6	3.38 ± 1.22	5
Factors relevant for research						
Surgeon able to perform and interpret intraoperative cholangiography	33.8	2.44 ± 1.84	2	57.6	2.49 ± 1.66	1
Establishing the critical view of safety	38.5	1.82 ± 1.54	1	51.2	1.53 ± 1.08	2
Timing of operation with reference to disease history	17.6	2.85 ± 2.22	5	50.4	2.81 ± 1.67	3
Appropriate use of energy devices by surgeon	27.7	2.54 ± 2.2	3	34.4	2.51 ± 1.3	4
Recognize need for conversion or alternate procedure	14.9	2.68 ± 2.04	7	28.8	3.61 ± 2.42	5

Ordered according to % respondents who ranked item as a top-five item. Mean ranks given as mean ± SD

R1 rank overall item rank in first round of Delphi, *R2 rank* overall item rank in second round of Delphi

In addition to the items prioritized for research through the Delphi consensus as presented in this study, future research must also consider appropriate outcome measures. Commonly cited outcomes include morbidity, bile duct injury rates, time taken, or rates of conversion. However, these represent an outcomes-based, surgical perspective. It does not take into account what should perhaps be a more patient-focused approach in what is, after all, an operation performed for benign disease. Future studies should thus place greater emphasis on patient-oriented outcomes such as resolution of symptoms, or quality of life, in addition to traditionally reported surgical measures.

The strengths of the Delphi process are highlighted by the gradual refinement of items throughout the stages of this study. From 39 original NGT items, the staged Delphi process reduced these first to 26 and then to 15 items, with the Delphi process ensuring unbiased opinion sharing and achieving consensus across a larger group. Though the participants were drawn from a select group representing a small proportion of the greater community of laparoscopic gastrointestinal surgeons with a potential overrepresentation of academic centers, as SAGES committee members, the participating surgeons also represent those nominated to represent their peers on a national and international level. A suitable response rate (mean response rate 37 %) for the Delphi survey will have minimized any potential non-response bias [36].

The results of this consensus process form a preliminary "road map" toward the ultimate goal—improved outcomes and reduced injuries in LC. They also, however, illustrate some of the difficulties to be encountered along the way. Despite 39 items being put forward by the original Task Force group, consensus could only be reached on little more than a third of them (15/39, 38 %). Participant "buy-in" is critical to any initiative which takes on the difficult task of introducing change in established practice. Seeking to also instill changes in organizational safety culture is even more difficult. Recent studies of the WHO Safer Surgery Checklist, for example, have demonstrated the potential for failure which looms if initiatives are introduced without proper training, buy-in, and leadership—resulting in completed "tick-box exercises" without actual change, negative responses among staff, and stagnant patient outcomes [37, 38]. Such lessons highlight the

importance of achieving broad consensus, as presented in this study, to identify items of perceived greatest importance, which received the greatest support, and, therefore, have the greatest chance of succeeding in future.

Conclusion

In summary, this study reports the results of a Delphi consensus process intended to identify key items to ensuring safe practice in LC, as well as priorities for future training, assessment, and research. Across all domains, emphasis was placed upon safe establishment of the critical view of safety, in addition to appropriate surgical decision making, and intraoperative judgement. Priorities for educators, researchers, and surgeons alike have been identified, with which to structure a campaign to reduce bile duct injury rates and improve patient safety in cholecystectomy.

Disclosures Rajesh Aggarwal is a consultant for Applied Medical. Robert D. Fanelli is a consultant for EndoGastric Solutions and Cook Surgical, Inc. All other authors declare no financial ties or conflicts of interest.

Appendix 1

See Table 4

Table 4 Detailed Delphi consensus results

Importance of factors for safe cholecystectomy						
Answer	Delphi round 1			Delphi round 2		
	% Rating 4 or 5	Rating mean	Round 1 rank	% Rating 4 or 5	Rating mean	Round 2 rank
Adequate experience of primary surgeon	99.4	4.92 ± 0.1	1	98.6	4.93 ± 0.13	2
Knowing when to call for help (e.g., senior colleague)	98.8	4.86 ± 0.18	2	99.3	4.83 ± 0.16	1
Understanding of relevant anatomy	98.7	4.83 ± 0.17	3	97.8	4.64 ± 0.35	4
Appropriate intraoperative retraction and exposure	98.7	4.77 ± 0.21	4	98.6	4.67 ± 0.25	3
Establishing the critical view of safety (clearance of Calot's triangle; dissection of gallbladder for cystic plate; only two structures enter gall bladder)	96.9	4.74 ± 0.28	5	97.1	4.55 ± 0.31	5
Recognize need for conversion or alternate procedure	96.9	4.73 ± 0.27	6	96.4	4.57 ± 0.39	6
Avoidance of injury of right hepatic artery	96.3	4.69 ± 0.23	7	92.1	4.31 ± 0.37	7
Appropriate hemostasis	96.3	4.67 ± 0.35	8	82.7	4.22 ± 0.55	14
Recognize postoperative complications/deviations from expected postoperative course	96.2	4.63 ± 0.36	9	87.8	4.32 ± 0.57	10
Appropriate use of energy devices by surgeon	95.0	4.56 ± 0.35	10	87.1	4.25 ± 0.48	13
Securing of the cystic duct	95.0	4.56 ± 0.35	11	92.1	4.39 ± 0.4	8
Appropriate tissue handling	93.8	4.56 ± 0.45	12	87.8	4.34 ± 0.53	11
Appropriate decision to proceed with operation	93.8	4.55 ± 0.42	13	87.8	4.22 ± 0.45	12
Surgeon able to perform and interpret intraoperative cholangiography	92.5	4.53 ± 0.46	14	89.2	4.32 ± 0.46	9
Good trainer–trainee communication	91.3	4.43 ± 0.58	15	79.9	4.11 ± 0.62	16
Anticipation of difficult case and appropriate management	91.3	4.4 ± 0.49	16	78.4	4.14 ± 0.67	17
Appropriate establishment of pneumoperitoneum and port placement	90.0	4.38 ± 0.58	17	73.4	3.97 ± 0.83	22
Recognize when to refer to tertiary unit	89.4	4.49 ± 0.49	18	77.7	4.06 ± 0.62	18
Hospital availability of intraoperative cholangiography	88.8	4.45 ± 0.55	19	75.5	4.07 ± 0.69	20
Operating room setup and availability of equipment	88.1	4.3 ± 0.58	20	77.7	4.09 ± 0.73	19
Securing of the cystic artery	88.1	4.31 ± 0.62	21	75.5	3.96 ± 0.69	21
Maintained plane of dissection of gallbladder	86.8	4.3 ± 0.5	22	69.8	3.89 ± 0.63	24
Start dissection of Calot's triangle high on gallbladder	86.7	4.39 ± 0.69	23	80.6	4.19 ± 0.76	15
Intraoperative team communication	86.3	4.28 ± 0.7	24	73.4	4.02 ± 0.7	23
Preoperative patient workup	85.7	4.27 ± 0.61	25	66.9	3.82 ± 0.83	27
Do not persist with dissection in setting of severe inflammation/fused hepatocystic triangle	82.5	4.26 ± 0.87	26	69.1	3.97 ± 0.75	25

Table 4 continued

Importance of factors for safe cholecystectomy						
Answer	Delphi round 1			Delphi round 2		
	% Rating 4 or 5	Rating mean	Round 1 rank	% Rating 4 or 5	Rating mean	Round 2 rank
Management of patient comorbidities	78.9	4 ± 0.8	27	57.6	3.58 ± 0.87	30
Decompression of tense gallbladder prior to dissection	76.3	3.96 ± 0.69	28	58.3	3.65 ± 0.69	29
Team safety culture	75.6	4.09 ± 0.92	29	67.6	3.85 ± 1	26
Timing of operation with reference to disease history	73.0	3.96 ± 0.81	30	59.7	3.6 ± 0.81	28
Patient positioning on operating table	70.6	3.84 ± 0.91	31	48.2	3.46 ± 0.95	31
Patient education	63.5	3.73 ± 1.22	32	41.7	3.27 ± 1.24	33
Prioritizing difficult procedures on the operating room schedule	56.3	3.59 ± 1.06	33	43.2	3.29 ± 1.05	32
Appropriate assistant skill level	52.2	3.51 ± 1.01	34	41.0	3.32 ± 0.97	34
Preoperative discussion of case with anesthesiologist	44.4	3.23 ± 1.12	35	33.1	3.09 ± 0.89	35
Intraoperative "time-out" to confirm critical view of safety	40.6	3.18 ± 1.64	36	25.2	2.83 ± 1.33	37
Preoperative team briefing ("huddle")	33.5	3.06 ± 1.4	37	26.6	2.78 ± 1.28	36
Postoperative team debriefing	32.5	2.99 ± 1.28	38	23.0	2.6 ± 1.27	38
Photographic documentation of critical view of safety	28.1	2.82 ± 1.75	39	17.3	2.49 ± 1.19	39

Appendix 2

See Table 5

Table 5 Results of Delphi consensus to select top five factors relevant to training

Answer options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Establishing the critical view of safety	87.8	1.52 ± 0.92	1	92.0	1.59 ± 0.98	1
Appropriate intraoperative retraction and exposure	58.8	2.57 ± 1.32	2	69.6	2.66 ± 1.09	3
Start dissection of Calot's triangle high on gallbladder	38.5	2.49 ± 0.9	3	52.0	2.97 ± 1.28	4
Understanding of relevant anatomy	35.8	3.11 ± 1.95	4	84.0	2.51 ± 1.48	2
Surgeon able to perform and interpret intraoperative cholangiography	31.8	2.89 ± 1.27	5	37.6	4.28 ± 0.9	6
Appropriate use of energy devices by surgeon	31.8	3.66 ± 1.19	6	27.2	3.97 ± 0.76	7
Do not persist with dissection in setting of severe inflammation/ fused hepatocystic triangle	29.7	3.66 ± 1.39	7	22.4	3.75 ± 1.23	9
Knowing when to call for help (e.g., senior colleague)	22.3	3.91 ± 1.4	8	38.4	4.04 ± 1.15	5
Recognize need for conversion or alternate procedure	20.9	3.65 ± 1.64	9	27.2	4.15 ± 0.86	8
Appropriate tissue handling	20.3	3.87 ± 1.29	10	8.8	3.64 ± 1.65	10
Securing of the cystic duct	16.9	3.88 ± 1.11	11	1.6	5 ± 0	17
Appropriate establishment of pneumoperitoneum and port placement	16.9	2.76 ± 1.86	12	6.4	4.13 ± 0.7	11
Maintained plane of dissection of gallbladder	12.2	3.67 ± 1.41	13	1.6	3.5 ± 4.5	18
Securing of the cystic artery	7.4	4.09 ± 0.69	14	0.0		24
Appropriate hemostasis	7.4	4.09 ± 1.89	15	0.8	4	21
Anticipation of difficult case and appropriate management	6.8	3.5 ± 0.94	16	4.8	3.17 ± 3.37	13
Avoidance of injury of right hepatic artery	6.1	3.78 ± 0.69	17	0.0		24

Table 5 continued

Answer options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Adequate experience of primary surgeon	6.1	3.78 ± 2.94	18	4.8	2.67 ± 3.47	14
Recognize postoperative complications/deviations from expected postoperative course	5.4	4.5 ± 0.57	19	6.4	4.13 ± 0.98	12
Good trainer–trainee communication	4.7	3.29 ± 1.9	20	2.4	3.33 ± 2.33	16
Appropriate decision to proceed with operation	4.1	4 ± 2.4	21	4.0	4.2 ± 1.7	15
Decompression of tense gallbladder prior to dissection	3.4	4 ± 1	22	0.0		24
Team safety culture	2.7	4.5 ± 1	23	1.6	2.5 ± 4.5	19
Preoperative patient workup	2.7	1.25 ± 0.25	24	0.8	1	22
Recognize when to refer to tertiary unit	2.0	4.33 ± 0.33	25	0.0		24
Intraoperative team communication	1.4	3.5 ± 0.5	26	0.8	4	23
Intraoperative "time-out" to confirm critical view of safety	1.4	4.5 ± 0.5	27	0.0		24
Patient positioning on operating table	1.4	4.5 ± 0.5	28	1.6	4 ± 0	20
Timing of operation with reference to disease history	1.4	3 ± 0	29	0.0		24
Management of patient comorbidities	1.4	4 ± 2	30	0.0		24
Operating room setup and availability of equipment	0.7	2.00	31	0.0		24
Appropriate assistant skill level	0.7	3.00	32	0.0		24
Patient education	0.7	1.00	33	0.0		24
Prioritizing difficult procedures on the operating room schedule	0		34	0		24
Photographic documentation of critical view of safety	0		34	0		24
Hospital availability of intraoperative cholangiography	0		34	0		24
Preoperative discussion of case with anesthesiologist	0		34	0		24
Preoperative team briefing ("huddle")	0		34	0		24
Postoperative team debriefing	0		34	0		24

Appendix 3

See Table 6

Table 6 Results of Delphi consensus to select top five factors relevant to assessment

Answer Options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Establishing the critical view of safety	85.1	1.31 ± 0.6	1	92.0	1.24 ± 0.43	1
Surgeon able to perform and interpret intraoperative cholangiography	48.0	2.56 ± 1.08	2	67.2	2.95 ± 1.52	3
Appropriate intraoperative retraction and exposure	39.9	2.8 ± 1.54	3	59.2	2.96 ± 1.16	4
Appropriate use of energy devices by surgeon	31.8	3.47 ± 1.3	4	33.6	3.38 ± 1.22	5
Understanding of relevant anatomy	31.1	2.83 ± 1.92	5	75.2	2.95 ± 1.6	2
Start dissection of Calot's triangle high on gallbladder	21.6	2.75 ± 1.35	6	31.2	3.69 ± 0.9	6
Recognize need for conversion or alternate procedure	20.3	3.43 ± 1.84	7	24.8	3.97 ± 1.03	7
Do not persist with dissection in setting of severe inflammation/fused hepatocystic triangle	17.6	3.77 ± 0.98	8	13.6	3.94 ± 1.31	8
Maintained plane of dissection of gallbladder	16.2	3.67 ± 1.1	9	8.0	3.6 ± 1.6	12
Securing of the cystic duct	15.5	3.35 ± 1.06	10	8.8	3.73 ± 0.82	11
Appropriate tissue handling	14.9	3.77 ± 1.23	11	10.4	4.23 ± 1.36	9

Table 6 continued

Answer Options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Knowing when to call for help (e.g., senior colleague)	12.8	4 ± 0.89	12	9.6	4.25 ± 0.57	10
Adequate experience of primary surgeon	12.2	3.06 ± 2.06	13	5.6	3.86 ± 2.48	15
Securing of the cystic artery	10.8	3.88 ± 1.05	14	4.8	4.5 ± 0.3	16
Intraoperative "time-out" to confirm Critical View of Safety	8.8	3.69 ± 2.23	15	3.2	3.25 ± 4.25	19
Appropriate establishment of pneumoperitoneum and port placement	8.1	3 ± 2	16	1.6	4.5 ± 0.5	22
Recognize postoperative complications/deviations from expected postoperative course	6.8	4.6 ± 0.49	17	7.2	4.44 ± 0.28	13
Photographic documentation of Critical View of Safety	6.1	3.44 ± 1.28	18	7.2	3.22 ± 1.94	14
Timing of operation with reference to disease history	5.4	3.75 ± 2.21	19	0.8	4	24
Decompression of tense gallbladder prior to dissection	4.7	3.14 ± 1.14	20	1.6	4.5 ± 0.5	23
Appropriate hemostasis	4.7	3.86 ± 2.14	21	0.8	5	25
Team safety culture	4.7	4.29 ± 0.57	22	4.0	3.4 ± 1.8	17
Good trainer–trainee communication	4.7	3.71 ± 0.9	23	2.4	5 ± 0	20
Anticipation of difficult case and appropriate management	4.7	3.57 ± 1.29	24	4.0	4.2 ± 0.7	18
Appropriate decision to proceed with operation	3.4	3.2 ± 1.7	25	0.8	2	26
Preoperative patient workup	3.4	2.2 ± 3.2	26	0.8	5	27
Intraoperative team communication	2.7	4.25 ± 0.25	27	0.0		30
Operating room setup and availability of equipment	2.7	4.25 ± 0.92	28	2.4	4.33 ± 1.33	21
Hospital availability of intraoperative cholangiography	2.7	3.5 ± 1	29	0.8	3	28
Recognize when to refer to tertiary unit	2.7	3 ± 1.33	30	0.0		30
Avoidance of injury of right hepatic artery	2.0	4 ± 1	31	0.0		30
Prioritizing difficult procedures on the operating room schedule	2.0	3 ± 1	32	0.0		30
Appropriate assistant skill level	1.4	3.5 ± 0.5	33	0.0		30
Patient positioning on operating table	1.4	4 ± 2	34	0.0		30
Preoperative discussion of case with anesthesiologist	1.4	3.5 ± 0.5	35	0.0		30
Preoperative team briefing ("huddle")	0.7	4	36	0.7	3	29
Management of patient comorbidities	0.7	5	37	0.0		30
Postoperative team debriefing	0.7	5	38	0.0		30
Patient education	0		39	0		30

Appendix 4

See Table 7

Table 7 Results of Delphi consensus to select top five factors relevant to research

Answer options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Establishing the critical view of safety	38.5	1.82 ± 1.54	1	51.2	1.53 ± 1.08	2
Surgeon able to perform and interpret intraoperative cholangiography	33.8	2.44 ± 1.84	2	57.6	2.49 ± 1.66	1
Appropriate use of energy devices by surgeon	27.7	2.54 ± 2.2	3	34.4	2.51 ± 1.3	4
Do not persist with dissection in setting of severe inflammation/fused hepatocystic triangle	18.2	2.63 ± 1.86	4	23.2	3.07 ± 1.85	7
Timing of operation with reference to disease history	17.6	2.85 ± 2.22	5	50.4	2.81 ± 1.67	3

Table 7 continued

Answer options	Delphi round 1			Delphi round 2		
	% of responses	Mean rank	Round 1 rank	% of responses	Mean rank	Round 2 rank
Understanding of relevant anatomy	16.9	2.52 ± 1.59	6	25.6	3.34 ± 1.52	6
Recognize need for conversion or alternate procedure	14.9	2.68 ± 2.04	7	28.8	3.61 ± 2.42	5
Intraoperative team communication	14.9	3.36 ± 2.43	8	18.4	3.22 ± 1.54	11
Photographic documentation of critical view of safety	14.9	2.5 ± 2.17	9	20.0	2.52 ± 2.01	8
Intraoperative "time-out" to confirm critical view of safety	14.2	2.71 ± 1.71	10	19.2	3.13 ± 1.85	10
Team safety culture	12.8	2.74 ± 1.54	11	20.0	3.4 ± 1.92	9
Appropriate intraoperative retraction and exposure	12.2	3.5 ± 1.79	12	6.4	3.63 ± 1.13	17
Recognize postoperative complications/deviations from expected postoperative course	11.5	3.18 ± 1.78	13	9.6	3 ± 1.82	14
Adequate experience of primary surgeon	10.8	2.75 ± 1.93	14	5.6	3.71 ± 1.24	19
Prioritizing difficult procedures on the operating room schedule	10.8	3.06 ± 1.8	15	10.4	3.38 ± 1.76	12
Avoidance of injury of right hepatic artery	8.8	2.92 ± 2.41	16	2.4	4.67 ± 0.33	26
Knowing when to call for help (e.g., senior colleague)	8.1	2.58 ± 2.81	17	7.2	4.11 ± 1.36	16
Anticipation of difficult case and appropriate management	8.1	3.33 ± 0.97	18	10.4	3.15 ± 1.14	13
Maintained plane of dissection of gallbladder	6.8	3.7 ± 1.57	19	4.0	4.4 ± 0.8	23
Appropriate tissue handling	6.8	4 ± 1.56	20	2.4	2.67 ± 4.33	27
Appropriate assistant skill level	6.8	2.8 ± 1.96	21	5.6	3.14 ± 2.48	20
Good trainer–trainee communication	6.8	2.7 ± 1.34	22	9.6	3 ± 2	15
Recognize when to refer to tertiary unit	6.8	3.4 ± 2.04	23	4.8	3.83 ± 1.37	21
Start dissection of Calot's triangle high on gallbladder	6.1	2.78 ± 2.44	24	6.4	4 ± 1.71	18
Decompression of tense gallbladder prior to dissection	6.1	4 ± 0.75	25	3.2	4 ± 0	25
Hospital availability of intraoperative cholangiography	6.1	2.78 ± 2.19	26	2.4	3.67 ± 1.33	28
Patient education	6.1	3.22 ± 1.44	27	4.8	2.67 ± 1.07	22
Securing of the cystic duct	5.4	3.5 ± 2.86	28	1.6	4.5 ± 0.5	30
Appropriate establishment of pneumoperitoneum and port placement	5.4	3.5 ± 2.29	29	4.0	3.6 ± 1.3	24
Postoperative team debriefing	5.4	2.75 ± 1.93	30	1.6	5 ± 0	31
Appropriate hemostasis	4.7	3.71 ± 1.9	31	0.0		36
Operating room setup and availability of equipment	4.1	3.33 ± 0.67	32	0.0		36
Preoperative team briefing ("huddle")	4.1	3.17 ± 0.57	33	1.6	4 ± 0	32
Appropriate decision to proceed with operation	3.4	2 ± 3	34	0.7	5	34
Management of patient comorbidities	3.4	3 ± 3.5	35	2.0	4 ± 3	29
Securing of the cystic artery	2.7	2.75 ± 2.25	36	0.0		36
Preoperative patient workup	2.7	4 ± 0.67	37	0.0		36
Patient positioning on operating table	1.4	3.5 ± 4.5	38	0.7	5	35
Preoperative discussion of case with anesthesiologist	1.4	4 ± 0	39	1.4	4.5 ± 0.5	33

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