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ORIGINAL ARTICLE

Key components of a hepatobiliary surgery curriculum for general surgery residents: results of the *FULCRUM* International Delphi consensus

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Abstract

Background: In general surgery residency, hepatobiliary training varies significantly across the world. The aim of this study was to establish an international consensus among hepatobiliary surgeons on components of a hepatobiliary curriculum for general surgery residents.

Methods: A three-round modified Delphi technique was employed. Fifty-two hepatobiliary surgeons involved in general surgery training programs were invited. An initial questionnaire was developed by a group of experts in hepatobiliary and educational research after a systematic literature review. It comprised 90 statements about knowledge, technical skills, attitudes, and postoperative care. Panelists could add or alter items. The survey was delivered electronically and the panel was instructed to score the items based on 5-point Likert scale. Consensus was reached when at least 80% of panelists agreed on a statement with Cronbach's alpha value >0.8.

Results: Forty-one (79%) experts have participated. Sixteen panelists are based in Asia, 14 in Europe, and 11 in the Americas. Eighty percent of all proposed skills (81/101) were considered fundamental including knowledge (39/43), technical skills (16/32), attitude (15/15), and postoperative care (11/11).

Conclusion: An international consensus was achieved on components of a hepatobiliary curriculum. Acquiring broad knowledge is fundamental during residency. Advanced liver resection techniques require specialized hepatobiliary training.

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Introduction

Hepatobiliary surgery has always been an essential part of general surgery training programs, but the learning objectives, content and integration into the existing curricula needs to be improved.[1]

[*] ***FULCRUM*** (***FU***ndamental Components of ***L***iver Surgery ***C***u***R***icul***UM***) research group comprises panelists who contributed to the Delphi process, listed in alphabetic order. All members have critically revised the article for important intellectual content and gave final approval of the version to be published.

The widespread move toward subspecialization has limited the training opportunities for general surgery residents. In many countries hepatobiliary procedures are mostly performed by fellowship-trained surgeons in hepatopancreatobiliary, surgical oncology, or abdominal transplantation.[2,3] The impact of subspecialization on general surgery residency programs varies among institutions worldwide. While the outcome of training ultimately depends on objectives of individual residents and programs, it is important to develop a stepwise curriculum and to standardize the training.[2,4,5]

In a survey-based assessment of graduated general surgeons entering surgical subspecialty fellowships in North America, fellowship program directors have raised concerns that general surgery residents are inadequately prepared to enter independent surgical practice or postgraduate subspecialty training.[6] To resolve the inadequacy of the general surgery training programs and standardize training, minimum skill requirements have been defined by worldwide medical and surgical councils. Despite research in some centers to evaluate the implementation of these criteria, training in hepatobiliary surgery during general surgery residency is still far from being standardized.[7] For instance, in the United States, according to Accreditation Council of Graduate Medical Education (*ACGME*), the minimum number of 5 liver procedures, and 85 biliary procedures are required during general surgery residency,[8] while the European Union of Medical Specialist (*UEMS*) has proposed a minimum number of 20 Liver and spleen (e.g. biopsy, organ injury, resection) and 50 biliary tract procedures, to be qualified as a general surgeon. Of note, in this curriculum, hepatobiliary surgery is categorized under the large group of abdominal surgeries and as such, numeric deficits in one or more subcategories can be compensated by higher numbers in other groups.[9] Thus, in hepatobiliary surgical education, improving the current curricula and standardizing training programs are priorities in multi-institutional surgical education research.[10] A consensus among experts is a recognized strategy for program planning, needs assessment and curriculum development.[11] Among the available methods, the Delphi technique is a well suited tool to achieve a consensus of opinions concerning a specific topic.[12,13]

While every training curriculum is designed to supply local needs of health care systems and, therefore, varies widely across the world, an international approach to training may create a valuable resource to share experiences and to learn one from another. The aim of this study was to establish an international expert consensus by means of modified Delphi methodology on the fundamental skills that general surgery residents should acquire in hepatobiliary surgery. The Delphi panel will define the key competencies of hepatobiliary surgery to be considered when developing general surgery residency curricula.

Methods

Study design

This study was approved by the Ethical Committee of Ghent University Hospital in Belgium (IRB Approval No. B670201939600). The modified Delphi technique using online questionnaires was employed to obtain an international expert consensus on learning objectives of residency programs in hepatobiliary surgery. The Delphi methodology applies a blinded, structured, and interactive communication, where experts evaluate and re-evaluate statements in successive rounds toward collective agreement. The premise is to enhance individual judgment based on pooled intelligence without being physically assembled.[11,14] In the conventional Delphi technique the first round statements are formulated by the panel,[15,16] while in this study, a modified Delphi method through exploring the hepatobiliary surgery literature was used.[17,18] The Delphi statements were defined by a research group based on results of a systematic literature review, with focus on liver surgery education, according to the PRISMA guidelines.[19] MEDLINE through PubMed, Web of Science, Embase, Education Resource Information Center (ERIC) databases, conference proceedings, and gray literature including online national and international syllabuses, and curricula for hepatobiliary surgery, were searched. The objectives of different training programs, learned contents in three learning domains (knowledge, psychomotor and affective), implementation in surgical training curricula, and details of published curricula were considered in designing the items. The research group comprised three attending hepatobiliary surgeons experienced in liver surgery and surgical education from different continents (R.T, Z.M, A.A), two consultants competent in educational research (I.V.H, W.W), and one Ph.D. candidate conducting research on liver surgery education (N.R). None of these individuals participated in the Delphi rounds. After thorough discussion among the research group members, the initial questionnaire consisted of 90 statements and were categorized into knowledge, technical skills, attitude, and postoperative care. Demographic information of the selected Delphi participants, type of medical institution where they provide care, and type of hepatobiliary surgeries performed in their centers were collected in the first Delphi round.

Expert panel recruitment

The members of the expert panel were selected by purposive sampling based on their wealth of experience in liver surgery and contributions to general surgery training programs. An expert was defined as a currently practicing hepatobiliary surgeon who works in a teaching/university hospital and performs or supervises a minimum of 100 hepatobiliary procedures including at least 20 major hepatectomies annually. Although there is no consensus on the Delphi panel size in literature, 5 to 10 panelists in homogeneous groups and 15 to 30 panelists in heterogeneous populations have been recommended in previous studies.[11,20,21] The study aimed to have at least 10 participants from each continent (Asia, Europe and the Americas) and expected a response rate of approximately 60%. All participants gave written informed consent and their identity remained blinded during the study.

Delphi rounds

The study was performed utilizing an online platform (Survey Monkey® Inc., San Mateo, CA, USA). The Delphi was composed of two classic rounds and one extra round to validate the final components of the curriculum by the panelists. Each round was delivered via a personalized email,

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including a link to the survey and instruction for panelists. Participants were asked to rate the statements to be included in the curriculum based on a 5-point Likert scale from '1, Strongly disagree' to '5, Strongly agree'. Prospective validation of the survey warranted no missing data. The panel had 4 weeks to answer each round and up to 4 reminders were sent to non-responders. In case of no email response, participants were contacted by phone to avoid dropout between rounds. Free text boxes were available to comment and to suggest modification of statements. Experts were also encouraged to propose additional items or to remove statements that did not fit in the scope of general surgery training. Items were removed when more than two participants recommended that the statement was not in the level of general surgery practice. New statements and modifications proposed by panelists were collected and discussed in the research group to rephrase for clarity and were subsequently incorporated into the next round questionnaires.

After the first round, the results were anonymously analyzed and the suggested adjustments were applied by the research team. The distributions of scores (mean and standard deviation) and the agreement status (the percentage of panelists who scored ≥ 4) for each statement from the first round were circulated within the round 2 questionnaire. After data analysis of the second round, a third round was distributed to the participants containing the cumulative results of the previous rounds, a list of statements achieving consensus, and remaining items. Participants were requested to vote whether they agreed or disagreed to remove statements on which consensus was not met in two rounds.

Definition of consensus

Panel agreement was defined as 80% (32/41) or more of panelists scoring agree or strongly agree on a statement with concurrent overall Cronbach's alpha value of more than 0.8. These are reliable thresholds which have been used in previous Delphi studies.[22–24]

Statistics

Statistical analysis was performed using SPSS version 25.0 (IBM, Armonk, NY, USA). Final ranking of the statements was reported based on the second round agreement strength and the comparison of scoring between panelists from different continents were reported using mean values of the second round ratings. The Cronbach's alpha test was used to determine the internal consistency in the first and second round. The results were analyzed by non-parametric tests. The Kruskal–Wallis test was used to assess whether there were rating differences between panelists from different continents. A p value <0.05 was considered statistically significant. Pairwise p values were adjusted using simple Bonferroni correction for multiple comparisons and reported as adjusted p value.

Results

Panel

Out of a total of 52 invitations, 41 (79%) expert hepatobiliary surgeons agreed to participate in this study, representing 15 countries as shown in Table 1. Response rates from Asia, Europe, and the Americas were 16/19, 14/18, and 11/16, respectively. All experts were active in a teaching hospital (10 panelists) or an academic medical center (31 panelists) where both open and laparoscopic liver surgery are routinely performed. Demographics of the participants' centers are summarized in Table 2.

Delphi results

The study was performed from November 2018 to June 2019. The overall response rate was 100% both for the first and second round and 95% for the third round. As illustrated in Fig. 1, consensus was achieved for 81 (80%) out of 101 discussion subjects after executing three Delphi rounds. The items were clustered into knowledge (39/43), technical skills (16/32), attitude (15/15), and postoperative care (11/11) domains. Overall internal consistency was excellent in the first and second round (Cronbach's alpha: first 0.968; second 0.957).

First round

Consensus was noted on most of knowledge (32/40) and technical skills (16/29), but also for all statements on attitude (14/14) and postoperative care (7/7). Twenty-six statements were adjusted based on panel suggestions. Minor changes led to clarifications of the context, while major changes resulted in the addition of the term "basic knowledge" to a few statements of the knowledge section and changing the term "perform surgery" to "perform under supervision" or "assist in surgery" in the

Table 1 Represented countries from different continents

Country	Economy-Income	Participants
Hong Kong, China	High	1
Iran	Upper middle	1
Japan	High	9
Saudi Arabia	High	1
South Korea	High	2
Taiwan	High	2
Belgium	High	2
France	High	2
Germany	High	2
Italy	High	5
Spain	High	2
Switzerland	High	1
Canada	High	1
Mexico	Upper middle	1
United States of America	High	9

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Table 2 Demographics of participants' centers

Number of liver surgeries per year per center	Number of centers
<20	0/41
20–50	5/41
50–100	7/41
>100	29/41
Types of hepatobiliary surgeries	**Number of centers**
Open	41/41
Minimally invasive	41/41
Referral center for liver trauma	22/41
Ablation procedures	34/41
Liver transplantation	25/41
Members of the surgical team	**Median (range)**
Attending surgeons	5 (2–40)
Hepato-pancreato-biliary fellows/year	2 (0–7)
General surgery residents/year	3 (1–13)

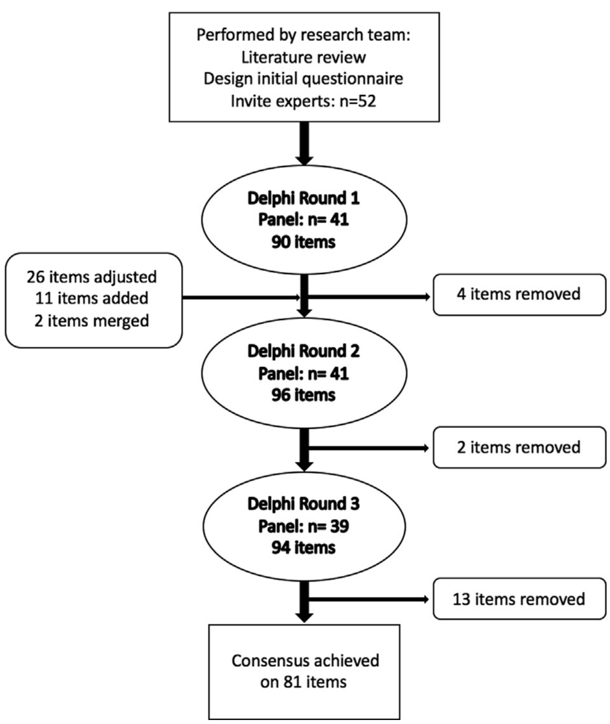

Figure 1 Fellowchart describing the Delphi process

technical skills section. Two statements were moved from the technical skills category to the knowledge domain (i.e. principles of intraoperative ultrasonography and tumor ablation procedures). Two items were merged to avoid redundancy (i.e. "Clinical hematologic and biochemical tests relevant to the liver", "Evaluation of liver static function (PT, Factor V & VIII, Albumin)"). Four statements were removed (i.e. "Knowledge of pathophysiology, presentation and natural history of the congenital liver disease", "Knowledge of indications for ALPPS and two staged hepatectomy" and "Performing porto-systemic shunt") because these were too complex for a residency program. Eleven new statements on knowledge (3), technical skills (3), attitude (1), and postoperative care (4) were added to the initial questionnaire.

Second round

The panel agreed to include all knowledge statements except for "Knowledge of basic liver embryology" and "Knowledge of sinusoidal blood flow". All items on attitude and postoperative care were highly rated and considered as key components of a hepatobiliary surgery curriculum. In the technical skills section, consensus was achieved for 16 out of 29 statements. The internal consistency for technical skills was excellent in both rounds (Cronbach's alpha: first 0.951; second 0.957).

Third round

All participants agreed to remove 13 technical skills statements from the curriculum which did not reach consensus in the previous rounds. Table 3 shows the excluded items in three rounds sorted in ascending order of agreement strength. All 81 final included statements are presented in Table 4, organized per category and sorted by last round agreement strength.

Inter-continental differences

There were no significant rating differences for knowledge, attitude, and postoperative care sections among panelist across continents. In contrast, some technical skill items were rated significantly different between experts from the Americas and Europe: "Preparing Pringle maneuver in minimally invasive liver surgery under supervision" (2.9 *vs* 3.9; adjusted $p = 0.023$), "Assist full liver mobilization in minimally invasive liver surgery" (2.8 *vs* 3.8; adjusted $p = 0.019$), "Assist minimally invasive minor anatomic liver resection" (3.2 *vs* 4.1; adjusted $p = 0.019$), "Assist minimally invasive major anatomic liver resection" (2.4 *vs* 3.4; adjusted $p = 0.044$). Experts from Asia scored "Perform minimally invasive cholangiography" significantly lower in comparison to their colleagues from Europe (4 *vs* 4.6; adjusted $p = 0.020$) and the Americas (4 *vs* 4.7; adjusted $p = 0.011$) (Fig. 2).

Discussion

This study aimed to identify the key components of a hepatobiliary surgery curriculum for general surgery residents and to provide an international resource that educators and policy makers can refer to, and apply to the local needs of their centers. A large international group of experts determined which competencies should be mastered during general surgery residency. A modified Delphi methodology was chosen owing to its inherent feasibility to gather expert's opinion while overcoming geographic constraint. Besides, the anonymous nature of the process guarantees that the outcome of the group is not

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Table 3 Final excluded items sorted in ascending order of agreement strength

Category	Statements	Removed on round	Mean (SD)	Median (IQR)	Consensus %
Knowledge	Knowledge of pathophysiology, presentation and natural history of the congenital liver disease	First	3.64 (0.9)	3 (1)	58
	Knowledge of indications for ALPPS and two staged hepatectomy	First	3.81 (1.2)	3 (2)	66
	Knowledge of basic liver embryology	Second	3.69 (0.7)	4 (1)	68
	Knowledge of sinusoidal blood flow	Second	3.78 (0.9)	4 (1)	70
Technical skills	Performing porto-systemic shunt	First	2.81 (1.07)	3 (2)	27
	Assist minimally invasive major anatomic resection (3 or more adjacent hepatic segments)	Third	3.10 (0.97)	3 (2)	39
	Assist full mobilization of liver in minimally invasive liver surgery	Third	3.64 (0.87)	3 (1)	44
	Perform open minor anatomic resection (less than 3 adjacent hepatic segments) under supervision	Third	3.56 (1.00)	3 (1)	54
	Preparing Pringle maneuver in minimally invasive liver surgery under supervision	Third	3.51 (0.93)	4 (1)	61
	Perform minimally invasive wedge resection under supervision	Third	3.59 (0.92)	4 (1)	61
	Assist minimally invasive minor anatomic resection (less than 3 adjacent hepatic segments)	Third	3.66 (0.85)	4 (1)	61
	Determine the indications for conversion of minimally invasive procedures to open or hand-assisted	Third	3.73 (0.95)	4 (1)	61
	Principles of tumor ablation procedures	First	3.83 (0.98)	4 (2)	63
	Perform operative external biliary drainage by Kehr's T- tube under supervision	Third	3.56 (1.21)	4 (2)	66
	Determine the appropriate port site placements for minimally invasive liver procedures	Third	3.66 (0.94)	4 (1)	66
	Perform bilio-enteric anastomosis under supervision	Third	3.85 (0.82)	4 (1)	68
	Perform pfannenstiel incision	Third	3.98 (0.82)	4 (1)	73
	Perform minimally invasive drainage of liver cyst or abscess (unroofing, resection) under supervision	Third	3.83 (0.80)	4 (0)	76
	Assist open major anatomic resection (3 or more adjacent hepatic segments)	Third	3.95 (0.80)	4 (0)	76

influenced by one or more persuasive panelists. Notably, the selected panelists for this study are true experts in the field, including numerous leading members of national and international liver surgery societies.

The recent trend toward organ and diseases-specific subspecialization clearly requires organ-oriented surgical training.[25] Such a surgical training program must assure proficiency in medical knowledge, technical skills, and patient care along with competency in self-reflection and assessment and interdisciplinary communications.[26] Therefore, a rather large number of items were divided into four categories in this study. General surgery residents were chosen as the target group because a stepwise hepatobiliary surgery training program should begin in general surgery and eventually be extended into a more complex and articulated subspecialization thereafter. The key skills identified in this study, should be assessed to certify that a general surgery specialist has the fundamental skills before being enrolled in any advanced hepatobiliary, oncology or abdominal transplantation subspecialty programs. Such proficiency metrics may also serve to ensure that a graduated general surgeon has the core competencies to examine patients with hepatobiliary disease, to make the appropriate decisions, to perform certain hepatobiliary procedures within a general surgical practice, and to refer when indicated.

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Table 4 Final included items sorted in descending order of agreement strength

N.	Knowledge statements	Mean (SD)	Median (IQR)	Consensus %
1	Knowledge of biliary tract anatomy including gallbladder	4.98 (016)	5 (0)	100
2	Knowledge of liver surface anatomy (ligaments, adjacent organs)	4.98 (0.16)	5 (0)	100
3	Knowledge of liver vascular anatomy	4.93 (0.26)	5 (0)	100
4	Knowledge of common anatomic variations	4.80 (0.40)	5 (0)	100
5	Knowledge of indication for surgical approach to liver metastases	4.73 (0.45)	5 (1)	100
6	Knowledge of how to evaluate patients with benign neoplasms of the liver and interpretation of imaging	4.68 (0.47)	5 (1)	100
7	Pathophysiological aspects of liver surgery in cirrhosis and definition of Child's score and MELD score	4.59 (0.50)	5 (1)	100
8	Knowledge of indications for liver transplantation	4.59 (0.50)	5 (1)	100
9	Diagnosis of patients presenting with liver abscess	4.37 (0.49)	4 (1)	100
10	Management of patients presenting with liver abscess	4.37 (0.49)	4 (1)	100
11	Clinical hematologic and biochemical tests relevant to the liver	4.85 (0.42)	5 (0)	98
12	Knowledge of Couinaud's segmentation	4.78 (0.47)	5 (1)	98
13	Knowledge of physiology and pathophysiology of coagulation	4.66 (0.53)	5 (1)	98
14	Knowledge of indication for surgical approach to hepatocellular carcinoma	4.66 (0.53)	5 (1)	98
15	Interpretation of imaging: differentiate liver tumors based on radiologic findings in collaboration with radiologist	4.49 (0.55)	4 (1)	98
16	Knowledge of indicators of portal hypertension	4.37 (0.73)	4 (1)	98
17	Knowledge of porto-systemic communications	4.32 (0.52)	4 (0)	98
18	Knowledge of indication and timing of liver vascular exclusion and Pringle maneuver	4.68 (0.65)	5 (1)	95
19	Knowledge of modality of choice for diagnosis of different liver tumors (CT-Scan, MRI, PET-Scan)	4.59 (0.67)	5 (1)	95
20	Knowledge of physiology and pathophysiology of bilirubin metabolism	4.44 (0.59)	4 (1)	95
21	Knowledge of indications for biliary tree drainage either by endoscopy or trans-hepatic approach	4.39 (0.67)	4 (1)	95
22	Evaluation of liver function: Static (PT, Factor V, VII, Bilirubin, Albumin) and dynamic (clearance tests, ICG, scintigraphy….)	4.34 (0.76)	4 (1)	95
23	Diagnose and classify acute and chronic liver failure	4.32 (0.85)	4 (1)	95
24	Knowledge of basic pathophysiology, presentation and natural history of the acquired non-neoplastic liver disease (hepatitis, cirrhosis, NASH, PSC, PBS)	4.15 (0.48)	4 (0)	95
25	Knowledge of basic liver histology (type of cells and their function)	4.12 (0.56)	4 (0)	95

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Table 4 (*continued*)

N.	Knowledge statements	Mean (SD)	Median (IQR)	Consensus %
26	Diagnosis and hemodynamic management of patients with liver trauma	4.29 (0.60)	4 (1)	93
27	Surgical management of patients with liver trauma	4.27 (0.59)	4 (1)	93
28	Knowledge of indications and principles of parenchymal sparing liver surgery	4.20 (0.60)	4 (1)	93
29	Knowledge of benefits and limitations of minimally invasive liver surgery	4.29 (0.78)	4 (1)	90
30	Knowledge of indications and contraindications for ablation therapies (MWA, RFA)	4.32 (0.76)	4 (1)	88
31	Knowledge of Brisbane classification for anatomic liver surgery	4.32 (0.88)	4 (1)	88
32	Interpretation of imaging: assessment of the tumor resectability	4.27 (0.81)	4 (1)	88
33	Knowledge of liver lymphatic drainage and nodal anatomy during oncological resection	4.15 (0.61)	4 (1)	88
34	Develop a detailed operative strategy for liver resections based on preoperative assessment and imaging	4.10 (0.97)	4 (1)	88
35	Interpretation of imaging: assessment of future liver remnant in collaboration with radiologist	4.07 (0.82)	4 (1)	88
36	Knowledge of general criteria of treating Klatskin tumors	4.10 (0.86)	4 (1)	83
37	Knowledge of physiology of other clinically relevant metabolic pathways (i.e.: hepatotoxic drugs, effect of chemotherapy on liver function, carbohydrate metabolism, …)	4.05 (0.59)	4 (1)	83
38	Knowledge of indication for portal vein embolization and radio-embolization	3.95 (0.84)	4 (0)	83
39	Knowledge of principles of intraoperative ultrasonography.	3.98 (0.91)	4 (1)	80
N.	**Technical skills statements**	**Mean (SD)**	**Median (IQR)**	**Consensus %**
1	Perform minimally invasive cholecystectomy	4.88 (0.33)	5 (0)	100
2	Preparing Pringle maneuver in open liver surgery	4.73 (0.45)	5 (0)	100
3	Principle of bleeding control, abdominal packing and Pringle maneuver in liver trauma	4.71 (0.46)	5 (1)	100
4	Usage of hemostatic technique (suturing, compression, clamp, clipping, usage of cautery devices, …)	4.63 (0.53)	5 (1)	98
5	Perform open cholecystectomy	4.76 (0.54)	5 (0)	98
6	Usage and installation of liver surgery retractors	4.49 (0.55)	4 (1)	98
7	Usage of hemostatic materials (TachoSil, Surgicel, …)	4.22 (0.65)	4 (1)	98
8	Determine the appropriate abdominal wall incisions in open liver procedures	4.51 (0.55)	5 (1)	95
9	Perform minimally invasive cholangiography	4.41 (0.63)	5 (1)	95

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Table 4 (*continued*)

N.	Technical skills statements	Mean (SD)	Median (IQR)	Consensus %
10	Perform open liver biopsy	4.32 (0.72)	4 (1)	93
11	Perform open cholangiography	4.49 (0.68)	5 (1)	90
12	Perform full mobilization of liver in open liver surgery	4.39 (0.70)	5 (1)	88
13	Perform open wedge liver resection	4.12 (0.84)	4 (1)	88
14	Perform open drainage of liver cyst or abscess (unroofing, resection)	4.00 (0.67)	4 (0)	83
15	Usage of CUSA or water-jet, sealing devices and staplers	3.98 (0.64)	4 (0)	83
16	Perform minimally invasive liver biopsy	4.02 (0.72)	4 (0)	80
N.	**Attitude statements**	**Mean (SD)**	**Median (IQR)**	**Consensus %**
1	Know own limitations and call for help from his/her supervisor	4.90 (0.30)	5 (0)	100
2	Provide preoperative relevant images of patient in the operation room	4.73 (045)	5 (1)	100
3	Check preoperative prophylaxis against common complications: DVT, infection	4.73 (0.45)	4 (1)	100
4	Anticipation of blood loss and asking for cell saver and blood products if indicated (e.g. massive transfusion protocols)	4.34 (0.76)	4 (1)	98
5	Provide and record clear and appropriate operative reports	4.73 (0.55)	5 (0)	95
6	Participate in multi-disciplinary meetings for malignant liver disorder	4.59 (0.71)	5 (1)	95

Table 4 (*continued*)

N.	Attitude statements	Mean (SD)	Median (IQR)	Consensus %
7	Inform patients of the type of liver surgery and its related risks. (= inform consent)	4.44 (0.63)	4 (1)	95
8	Check necessary equipment for intraoperative cholangiography	4.39 (0.54)	4 (1)	95
9	Knowledge of required anesthesiology consideration for liver surgery	4.37 (0.62)	4 (1)	95
10	Knowledge of usage and choice of surgical devices and back-up tools	4.39 (0.67)	5 (1)	88
11	Give briefing to operation room team (anesthesiology team, nurses …) prior to start the procedure.	4.34 (0.66)	4 (1)	88
12	Appropriate and safe positioning of patient on table in open liver surgeries	4.29 (0.72)	4 (1)	88
13	Appropriate and safe positioning of patient on table in minimally invasive liver surgeries	4.17 (0.86)	4 (1)	88
14	Check equipment and devices with the nurses prior to start the procedure	4.20 (0.82)	4 (1)	80
15	Be able to lead the team during elective and emergency operations	4.05 (0.80)	4 (1)	80
N.	**Postoperative care statements**	**Mean (SD)**	**Median (IQR)**	**Consensus %**
1	Routine postoperative cares including: wound care, patient mobilization, nutrition management, pain management, fluid balance and respiratory care	4.92 (0.26)	5 (0)	100

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Table 4 (*continued*)

N.	Postoperative care statements	Mean (SD)	Median (IQR)	Consensus %
2	Drain management including diagnosis of bile leakage, bleeding, and timely removal of the drain	4.78 (0.41)	5 (0)	100
3	Prophylaxis for DVT and advise on anticoagulant agent, indications and contraindications after surgery	4.78 (0.41)	5 (0)	100
4	Structured orders before discharge to recovery or PACU (Post Anesthesia Care Unit)	4.75 (0.43)	5 (0)	100
5	Request required post-operative laboratory tests and interpret them	4.75 (0.43)	5 (0)	100
6	Indication of antibiotic therapy after liver surgery	4.71 (0.46)	5 (1)	100
7	Be able to recognize alarm signs of post-operative liver failure	4.61 (0.49)	5 (1)	100
8	Be able to recognize post-operative bleeding and decide for urgent re-operation if indicated	4.54 (0.67)	5 (1)	98
9	Basics of post-operative intensive care after major liver surgeries	4.27 (0.55)	4 (1)	95
10	Indication of post-operative Doppler ultrasonography after liver surgery and liver transplantation	4.24 (0.58)	4 (1)	90
11	Know characteristics of ERAS (Enhanced Recovery After Surgery) protocol and apply it if indicated	4.10 (0.66)	4 (0)	88

Knowledge skills

The results of this study showed that providing trainees with a broad and profound knowledge in hepatobiliary surgery is fundamental during residency; yet, knowledge of embryology, sinusoidal blood flow, congenital liver disease, and knowledge of indications for ALPPS and two-staged hepatectomy were considered beyond the scope of general surgery training. In addition, scientific contribution is expected during residency (i.e. writing a paper, congress participation, etc.) and minimum activity is mandatory in lots of training programs; however, given the fact that this curriculum is targeting all general surgery residents with different fields of interest, hepatobiliary-oriented research was not considered as a key component. During both rounds of ranking statements, items focusing on hepatobiliary anatomy and common anatomic variations were scored very high. These findings emphasize that mastering the relevant anatomical knowledge is the first step in surgical training and surgeons must always be mindful of anatomical variations to ensure patient safety during hepatobiliary procedures.[27]

Technical skills

The current study demonstrates that after completion of general surgery residency, competency in basic hepatobiliary surgery procedures is required. Noteworthy, general surgeons have to be prepared to deal with liver bleeding either from trauma or intra-operative misadventure. As such, familiarity with retractors and instrumentation and proficiency in liver mobilization and hemostatic techniques are crucial. Also, surgical residents must be adequately trained in biliary surgery including minimally invasive and open cholecystectomy and cholangiography. Of note, repair of bile duct injuries seems to be considered too high-level for general surgery practice. Indeed, several studies have emphasized the importance of referring patients with bile duct injuries after cholecystectomy to specialized hepatobiliary units.[28–30] Likewise, according to this consensus, advanced liver resection techniques either open or minimally invasive are beyond the scope of a general surgery curriculum and require specialized training in hepatobiliary surgery. Extensive volume-outcome data strongly support these statements with lower in-hospital mortality and morbidity when liver resections are performed in specialized high-volume centers.[31,32] Moreover, the worldwide implementation of minimally invasive liver surgery may also play a role in changing paradigm of general surgery training. While laparoscopic liver surgery is recognized by a steep learning curve, in several hepatobiliary surgery training programs worldwide, there is insufficient experience and the number of complex minimally invasive procedures is too low even for fellowship training.[33] Therefore, specific postgraduate education under proctorship in centers with experience in minimally invasive procedures is recommended.[3,34]

Attitudes

All non-technical items describing professional behavior, communication skills, leadership, documentation (i.e. writing operative reports) and patient safety elements were highly rated. Previous studies have proven that professional skills are transferable through a structured education,[35] and training in non-

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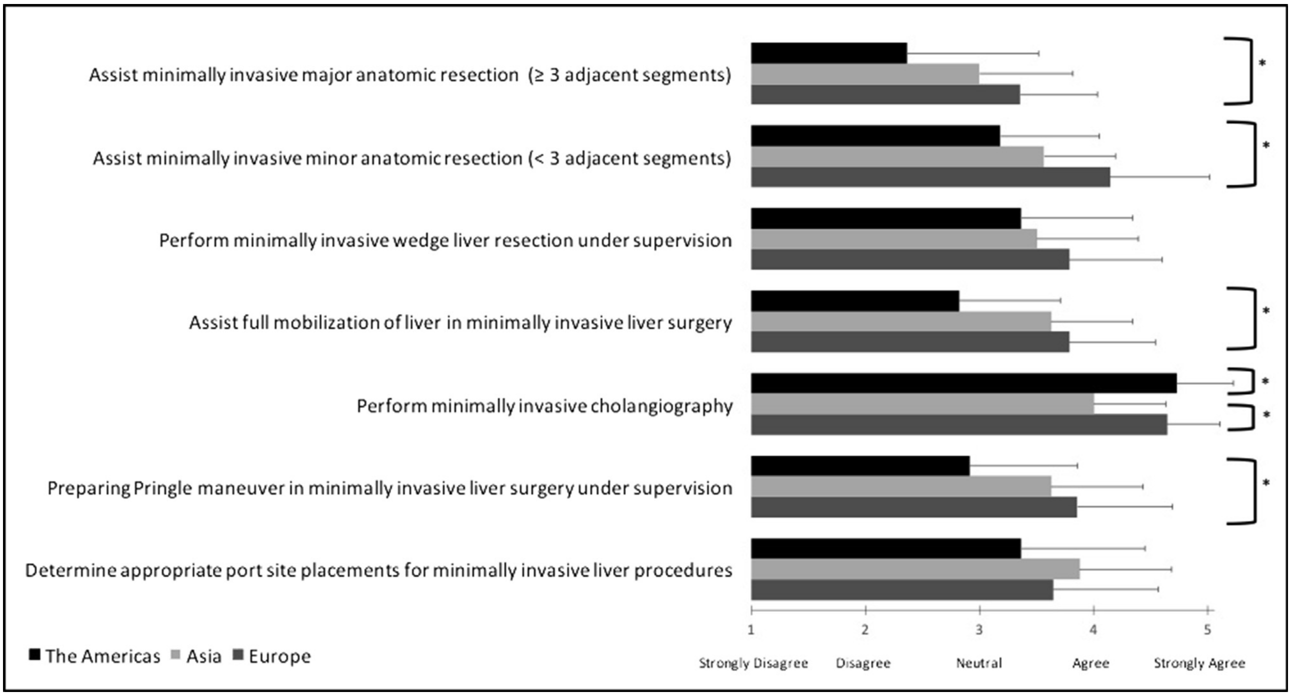

Figure 2 Panel rating to training in minimally invasive liver surgery techniques across continents (**asterisk* represents significant differences)

technical skills, including human factors and teamwork, are integral components in surgical skills acquisition.[36,37] This consensus reflects the emphasis of experts on non-technical surgical skills training. Particularly, the panel highlighted the importance of self-assessment and individuals recognizing their own limitations. The ability to critically assess one's own performance in surgery is not only crucial during the training, but also has tremendous importance for continuing professional development and can be improved by increasing experience.[38] Thus self-assessment along with formative feedback from educators are vital parts of a structured surgical training plan.[39]

Postoperative care

All items about postoperative care were perceived as fundamental parts of a general surgery curriculum. Liver surgery is a challenging procedure for both surgeons and patients and justifies the need for a standardized Enhanced Recovery After Surgery (ERAS) protocol.[40] Therefore, general surgeons must be trained to provide postoperative care according to standardized protocols and good practice points.

Inter-continental differences

There was no significant difference of opinion among panelists from three continents about knowledge, attitude and postoperative care skills. The facts that liver surgery is challenging, carrying potential risks, and is still under development in some aspects may explain the need for extensive education in knowledge, postoperative care and human factor skills. On the other hand, despite achieving a strong consensus in the technical skills section, competencies required for minimally invasive liver surgery were rated differently across continents (Fig. 2). European experts believe that providing exposure to basic minimally invasive liver surgeries in general surgery curricula is essential. There are several potential reasons to explain such discrepancies. In fact, an international consensus may define the core components of a training program, but every training curriculum must be tailored to local needs. The hierarchy of surgical education differs widely across the world based on requirements of served health care systems and the targeted population. Therefore, it is likely that a technical skill which is routinely taught to general surgery residents in one country is reserved for post-residency fellowship curriculum in another country. All panelists are derived from high or upper middle income countries according to the world bank income classifications. Thus, one might argue that the outcome of the current study mostly applies to wealthy health care systems; for example, the concept of training in minimally invasive liver surgery may actually be irrelevant to most low income health care systems.

Limitations

The Delphi methodology has been criticized to be potentially biased because the steering committee could limit the scope of the items and the expression of opinions.[41] These issues have been addressed in previous studies either by designing the initial framework by the panel or proposing an elaborate list of items to be rated.[41–43] To minimize the risk of bias in this study, the

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primary survey covered a vast range of items and the panel also had the possibility to add new statements. In addition, the steering committee consisted of liver surgeons from different continents to ensure that local practical traditions did not limit the scope of the study. Despite a very good response rate which resulted in a sample size compatible with current recommendations for Delphi studies,[11,20,21] the risk of selection bias cannot be excluded. The experts should not only meet the inclusion criteria, but also had to be sufficiently motivated to contribute in this time-consuming Delphi process. Thus sampling based on random participation was not feasible. Finally, although the modified Delphi technique is a validated method to achieve consensus among experts, it is subjective and does not guarantee leading toward a flawless solution.[37] Therefore, the implementation of the study results into a training program must be prospectively evaluated using robust designs.

Future perspectives

The long term objective of this project is to develop a stepwise proficiency-based training program for hepatobiliary surgery. This study has identified the priorities for researchers and educators to focus on while developing a curriculum. Further research is warranted to define and validate a liver surgery training program for general surgery residents. Surgical training based on a standardized program may produce general surgeons who are well prepared to either practice as an independent surgeon or pursue subspecialty fellowship.

Conclusion

Using the modified Delphi methodology, international consensus has been established among experts on fundamental components of a liver surgery curriculum for general surgery training. This is an important step toward developing a liver surgery curriculum starting from the basic level.

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Conflicts of interest

None declared.

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