Intraoperative ultrasonography and surgical strategy in hepatic resection: What difference does it make?

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Background: With modern advancements in preoperative imaging for liver surgery, intraoperative ultrasonography (IOUS) may be perceived as superfluous. Our aim was to determine if IOUS provides new information that changes surgical strategy in hepatic resection.

Methods: We retrospectively analyzed 121 consecutive liver resections performed at a single institution. Preoperative computed tomography and/or magnetic resonance imaging determined the initial surgical strategy. The size, location and number of lesions were compared between IOUS and preoperative imaging. Reviewing the operative report helped determine if new IOUS findings led to changes in surgical strategy. Pathology reports were analyzed for margins.

Results: Of 121 procedures analyzed, IOUS was used in 88. It changed the surgical plan in 15 (17%) cases. Additional tumours were detected in 10 (11%) patients. A change in tumour size and location were detected in 2 (2%) and 3 (4%) patients, respectively. Surgical plans were altered in 7 (8%) cases for reasons not related to IOUS. There was no significant difference ($p = 0.74$) in average margin length between the IOUS and non-IOUS groups (1.09 ± 1.18 cm v. 1.18 ± 1.05 cm).

Conclusion: Surgical strategy was altered owing to IOUS results in a substantial number of cases, and IOUS-guided resection planes resulted in R0 resections in nearly all procedures. The best operative plan in hepatic resection includes IOUS.

Contexte : Compte tenu des récentes avancées de l'imagerie préopératoire pour les chirurgies du foie, l'utilisation de l'échographie peropératoire pourrait paraître inutile. Notre objectif était de déterminer si cette pratique permet d'obtenir des images nouvelles motivant un changement de stratégie chirurgicale pendant une résection hépatique.

Méthodes : Nous avons analysé rétrospectivement 121 résections hépatiques consécutives réalisées dans un même établissement. La tomographie par ordinateur ou l'imagerie par résonance magnétique préopératoires ont été utilisées pour choisir la stratégie chirurgicale initiale. La taille et la position des tumeurs détectées ainsi que leur nombre ont été comparés selon la méthode utilisée : échographie peropératoire ou imagerie préopératoire. Nous avons étudié les rapports opératoires pour déterminer si l'échographie peropératoire avait entraîné un changement de stratégie chirurgicale et avons examiné les rapports de pathologie pour connaître les résultats de l'analyse des contours.

Résultats : L'échographie peropératoire a été utilisée dans 88 des 121 interventions étudiées. Elle a influé sur la stratégie chirurgicale dans 15 cas (17 %). De nouvelles tumeurs ont été détectées chez 10 patients (11 %), et un changement dans la taille ou la position de la tumeur a été détecté chez 2 (2 %) et 3 patients (4 %), respectivement. Dans 7 cas (8 %), la stratégie chirurgicale a été modifiée, mais pour des raisons indépendantes des résultats de l'échographie. Nous n'avons pas observé de différence significative ($p = 0,74$) entre la taille moyenne des contours pour les 2 groupes de patients, soit ceux qui ont été soumis à l'échographie peropératoire et ceux qui ne l'ont pas été ($1,09 \pm 1,18$ cm par rapport à $1,18 \pm 1,05$ cm).

Conclusion : La stratégie chirurgicale a été modifiée en fonction des résultats de l'échographie peropératoire dans un nombre important de cas, et dans presque tous les cas, l'échographie peropératoire a donné lieu à une résection complète. La meilleure approche lors d'une résection hépatique inclut donc l'échographie peropératoire.

Since its inception in the late 1980s, intraoperative ultrasonography (IOUS) has been an important adjunct in hepatic resection.¹ It can reveal new tumours not seen on preoperative imaging that would change surgical planning.²⁻⁷ Furthermore, IOUS provides new information about lesions and their association with vital anatomical structures to help guide resection planes.⁸⁻¹¹ Studies in the 1990s showed that new information from IOUS altered surgical strategy in up to 53% of cases.^{3,12} Contemporary studies demonstrate rates closer to 20%.^{9,13,14} The decline in rates could be attributed to important advances in preoperative imaging. In particular, computed tomography (CT) and magnetic resonance imaging (MRI) with bespoke liver protocols enhance preoperative image accuracy and quality.^{15,16} Given these imaging advances, it is necessary to ask whether IOUS still plays a role in modern hepatic resections.

The primary outcome of our study was to determine whether the use of IOUS leads to changes in surgical strategy and the reason for those changes. Our secondary outcome was to determine whether the use of IOUS impacts resection margins.

METHODS

Study design

We performed a single-institution retrospective study on 111 consecutive patients who underwent 121 operative procedures. The operations took place between February 2011 and July 2013 and were performed by 2 hepatobiliary surgeons. Both benign and malignant disease were included. In all resections, a preoperative CT or MRI scan was performed a mean of 45.3 ± 46.4 (range 1–424) days before the planned operation. Excluding 3 major outliers (1 patient with primary sclerosing cholangitis and 2 with metastatic breast cancer), preoperative imaging was performed a mean of 39.4 ± 25.8 (range 1–117) days before the operation. Diagnostic laparoscopy was used in all cases with an incidental finding of gallbladder cancer from previous cholecystectomy. Similarly, diagnostic laparoscopy was used in any patient with a high risk of peritoneal disease. Inspection via bimanual palpation through a small incision was used before every other open procedure.

The planned operation was documented in the last clinic note before the procedure. The operative note recorded the actual procedure performed. In cases that included IOUS, the staff radiologist or surgeon reported on the ultrasound findings. Staff radiologists compared these findings with preoperative imaging reports. We recorded any differences in number, size or location of lesions and whether these findings led to a change in operative plan.

We further stratified our procedures by diagnosis and type and analyzed whether these groupings impacted changes to surgical strategy. Given the small sample size in this study, we stratified procedures broadly in 3 ways: malignant versus

benign, laparoscopic versus open and minor (≤ 3 liver segments) versus major (> 3 liver segments) planned resection.

As a secondary outcome, we compared IOUS and non-IOUS groups for differences in resection margins. Using the final pathology report, the closest parenchymal margin out of all lesions was documented.

A single researcher gathered and entered all the data into a spreadsheet. The St. Joseph Health Centre research ethics board approved this study.

Statistical analysis

Descriptive statistics are reported as frequencies and means. We compared continuous variables using parametric *t* tests and categorical variables using the χ^2 test for independence. We considered results to be significant at $p < 0.05$. Analyses were performed using SAS software version 9.3 (SAS Institute Inc.).

RESULTS

Table 1 shows the patient demographic characteristics, diagnoses and types of imaging used in the IOUS and non-IOUS groups; 88 of the 121 procedures used IOUS and 33 did not. There was no significant difference in patient age, sex or diagnoses between the groups. A substantially greater percentage of patients in the non-IOUS group than in the IOUS group underwent preoperative MRI (70% v. 48%).

In the non-IOUS group, the preoperative plan was changed in 11 patients (Table 2). Carcinomatosis or advanced metastases on inspection led to an abortion in 8 cases. One case was aborted owing to portal vein and hepatic artery invasion. An extended bowel resection due to locally advanced tumour was required in 1 case. A misdiagnosed infection requiring abscess drainage instead of a hepatectomy and severe adhesions leading to a conversion changed the plan in 1 case each.

The surgical plan in the IOUS group changed in 7 (8%) cases for reasons not directly related to IOUS findings (Table 3). Additional tumours were found on inspection in

Table 1. Patient characteristics and imaging modalities

Characteristic	Group; no. (%) [*]			<i>p</i> value
	Total (<i>n</i> = 121)	IOUS (<i>n</i> = 88)	Non-IOUS (<i>n</i> = 33)	
Age, mean $\pm$ SD, yr	59.5 $\pm$ 13.3	58.5 $\pm$ 13.0	62.1 $\pm$ 13.7	0.19
Female sex	55 (45)	38 (43)	17 (52)	0.41
Preoperative imaging				
CT (≥ 1)	77 (64)	62 (70)	15 (45)	0.011
MRI	65 (54)	42 (48)	23 (70)	0.031
Ultrasonography	17 (14)	13 (15)	4 (12)	0.71
Postoperative diagnosis (malignant)	101 (83)	76 (86)	25 (76)	0.16

CT = computed tomography; IOUS = intraoperative ultrasonography; MRI = magnetic resonance imaging; SD = standard deviation.

^{*}Unless otherwise indicated.

4 patients. Three of them underwent extended resection. The remaining patient was changed to a much smaller resection owing to inadequate residual volumes. Liver conditions changed the operation in 3 patients. An unexpectedly cirrhotic liver led to a conversion from a laparoscopic to an open procedure in 1 patient and to a much smaller resection in another patient. Significant bleeding led to a conversion in the remaining case.

Conversely, IOUS directly led to a change in surgical plan in 15 (17%) cases (Table 3). Additional tumours were found in 10 patients. A more extensive resection was performed in 8 of them, and the remaining 2 cases were aborted. A significant change in tumour size and tumour location leading to an alteration in surgical plan was found in 2 and 3 cases, respectively. All 3 instances with shifts in location led to a more limited resection, as the tumour was confirmed to be away from critical adjacent structures. In 1 case where the tumour size changed the procedure was aborted owing to new vascular involvement, and in the other case an extended resection was planned, but was ultimately aborted owing to a positive celiac lymph node. The diagnoses in patients whose surgical plans were changed due to IOUS are outlined in Table 4.

The time interval between imaging and the operation did not impact changes in surgical strategy. The comparison of change versus no change in surgical strategy between the IOUS ($p = 0.82$) and non-IOUS ($p = 0.15$) groups was not significant. Similarly, within the IOUS group the comparison of changes due to IOUS, changes not due to IOUS and no changes in surgical strategy was not significant ($p = 0.85$).

Table 2. Changes in surgical plan in the non-IOUS group ($n = 33$)

Reason for change	No. (%) of changes, $n = 11$
Abort (carcinomatosis)	7 (21.2)
Abort (locally advanced tumour)	1 (3.0)
Conversion (adhesions)	1 (3.0)
Infection	1 (3.0)
Locally advanced tumour (extended resection)	1 (3.0)
IOUS = intraoperative ultrasonography.	

Table 3. Changes in surgical plan in the IOUS group ($n = 88$)

Reason for change	No. (%) of changes owing to IOUS, $n = 15$	No. (%) of changes not owing to IOUS, $n = 7$
Additional tumour(s) found via IOUS	10 (11.4)	0 (0)
Additional tumour(s) found via inspection	0 (0)	4 (4.5)
Liver conditions	0 (0)	3 (3.4)
Tumour location	3 (3.4)	0 (0)
Tumour size	2 (2.3)	0 (0)
IOUS = intraoperative ultrasonography.		

Stratification of the IOUS group did not produce any significant findings when analyzing impact on surgical change. A χ^2 test analyzed the stratification categories to surgical changes due to IOUS, changes not due to IOUS and no surgical change. Laparoscopic versus open ($p = 0.24$), benign versus malignant disease ($p = 0.61$) and major versus minor planned procedure ($p = 0.14$) were all nonsignificant.

Our secondary outcome was differences in margins between the IOUS and non-IOUS groups. There were no significant differences in margin length or R1 resection rate between the 2 groups (Table 5).

DISCUSSION

The major finding of our study shows that IOUS directly altered surgical plans in 17% of cases. The most recent study on IOUS, published in 2011, reported a 16.5% change in surgical strategy in operations for malignancies.⁵ Previous series published in the 2000s reported rates between 11.5% and 22.8%.^{14,17} These rates of change are decreasing; earlier studies published in the 1990s reported that surgical strategy was affected in 19%–53% of cases.^{3,4,12,18} While there was a historical decrease in rates between decades, our study results confirm that the impact of IOUS has plateaued over the last decade despite further advances in preoperative imaging. With the current rates of change in surgical strategy, it appears that modern preoperative imaging alone does not preclude the use of IOUS.

Our data show that in patients who did not undergo IOUS, 33% of cases had a surgical change. At first glance, this may suggest that this group experienced more surgical changes than the IOUS group (17%); however, 8 of the 11 cases in the non-IOUS group for which the surgical plan changed were aborted after initial inspection and before IOUS could be used owing to carcinomatosis or

Table 4. Diagnoses in operative plans changed due to IOUS

Diagnosis	No. (%) of changes owing to IOUS, $n = 15$
Gallbladder adenoma	1 (6.7)
Gallbladder cancer	1 (6.7)
Hepatocellular carcinoma	1 (6.7)
Cholangiocarcinoma	1 (6.7)
Metastatic colorectal cancer	10 (66.7)
Focal nodular hyperplasia	1 (6.7)

Table 5. Secondary outcome analysis

Factor	IOUS	Non-IOUS	p value
Margin length, mean $\pm$ SD, cm	1.09 $\pm$ 1.18	1.18 $\pm$ 1.05	0.74
R1 resection rate, no. (%)	3 (3.4)	2 (6.0)	0.61
IOUS = intraoperative ultrasonography; SD = standard deviation.			

tumour extension. None of the cases in the IOUS group for which the surgical plan changed were aborted owing to readily visible metastases, which precluded resection. As such, it would be reasonable to exclude the 8 aborted cases in the non-IIOUS group when assessing the difference in surgical change between the 2 groups. The non-IIOUS group would then have experienced a change in surgical plan for 3 of 33 (9%) cases, which is less than the 17% of change due to IOUS. The IOUS subset supports this finding, as 8% of cases in this group experienced a change in surgical plan that was unrelated to IOUS findings.

An unexpected finding of our study was that there was no difference in resection margins between the IOUS and non-IIOUS groups. A major function of IOUS has been to help surgeons define surgical planes. In 4 of our 15 cases that changed due to IOUS findings, the relationship of lesions to vascular structures played a major role in operative management. In the remaining IOUS cases, the surgeons noted that IOUS guided their planned resection. To our knowledge, no recent studies compare margin sizes between non-IIOUS and IOUS groups. Continued refinement in modern surgical technique is a possible explanation for this finding. Further, perhaps consulting preoperative imaging intraoperatively is as sensitive as IOUS in defining margin planes when the tumour location is known.

In our full cohort, 33 of the 121 procedures did not involve IOUS. The type of preoperative imaging used likely impacted the preoperative decision making to not perform IOUS. A substantially greater percentage of patients ($p = 0.031$) in the non-IIOUS group had preoperative MRIs. Multiple studies^{15,19,20} have shown that MRI has a much higher sensitivity than CT in detecting both malignant and non-malignant lesions. Sahani and colleagues²¹ compared the sensitivities of IOUS and MRI and reported that out of 159 histopathology-confirmed lesions analyzed, 12 (7.5%) lesions were seen only with IOUS. However, this finding did not achieve statistical significance, and the authors concluded that MRI was as sensitive as IOUS in detecting liver lesions. Despite this evidence, it should be noted that 8 of 15 patients whose procedures had a change in surgical plan owing to IOUS findings had a preoperative MRI. Experienced judgment must be carefully applied if one decides to forgo IOUS based on the presence of a preoperative MRI alone.

Apart from type of imaging, the surgeons at our institution agree that other factors influencing their decision to use IOUS include the method and extent of resection. However, there was no objective difference between the groups in laparoscopic cases ($p = 0.29$) or the number of major planned resections ($p = 0.27$). Eight of the 33 patients in the non-IIOUS group had their procedures aborted before they could undergo IOUS. Excluding these patients, 21% of the cohort did not undergo IOUS. Ultimately, subjective surgical judgment by the primary surgeon determined whether or not to use IOUS. Hopefully, studies such as ours can help standardized decision making in the use of IOUS.

There is heterogeneity within the subset of patients whose surgical plans changed owing to IOUS findings. Two different benign and 4 different malignant diseases are represented in this cohort (Table 4). The dominant diagnosis was metastatic colorectal cancer (67%). This is relatively proportional to the number of patients in our full cohort with this diagnosis (49%). While our sample size is too small to make any significant conclusions, these findings suggest that IOUS is useful in all liver surgery regardless of the diagnosis.

Limitations

A small sample size with a high degree of heterogeneity is one of the limitations of this study. We were unable to generate any meaningful conclusions on the impact of IOUS after stratifying our procedures by diagnosis and procedure. The retrospective nature of the study and lack of adequate control group also limit our findings. The person performing IOUS was not the same for all procedures, nor were these individuals blinded to the preoperative imaging results. Lack of blinding was for both logistical and ethical reasons and was a potential source of bias. In future, a prospective randomized trial with a larger number of patients with each diagnosis would provide more definitive evidence for the use of IOUS.

CONCLUSION

We found that IOUS directly altered the preoperative surgical plan in 17% of cases. There was no significant difference in positive margins between the IOUS and non-IIOUS groups. However, surgical planes were more easily defined with IOUS. Despite the modernization of preoperative imaging modalities, the best operative plan in hepatic resections still includes the use of IOUS.

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Contributors: R. Jreaz and S. Jayaraman designed the study. All authors acquired the data, which R. Jreaz and S. Jayaraman analyzed. R. Jreaz and S. Jayaraman wrote the article, which all authors reviewed and approved for publication.

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