French Editorial Commentary from the ACHBPT

National impact and advantages of the robotic approach to liver surgery in the era of minimally invasive surgery

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We read with great interest the study by Pilz da Cunha *et al.* (1), published in 2024, comparing outcomes of robotic and laparoscopic liver resections between 2014 and 2022, using data from the prospectively Dutch Hepatobiliary Audit. This study is significant given the context of minimally invasive surgery (MIS) playing an increasingly important role with a growing adoption of robotic-assisted approaches, supported by recent recommendations such as the Paris consensus (2). While numerous high-quality studies have compared laparoscopic or robotic with open surgery, studies directly comparing laparoscopic and robotic approaches remain limited.

This study included 3,530 MIS liver resections (laparoscopy: 2,738; robotics: 792) from 20 centers for any indication excluding total hepatectomies prior to liver transplantation, cholecystectomies, liver biopsies, fenestrations and emergency hepatic procedures. Following propensity score matching, 781 procedures were included per group. Matching variables included: gender, age, American Society of Anesthesiologists (ASA) score, Charlson comorbidity index, history of extrahepatic abdominal surgery, previous liver surgery, unilobar or bilobar liver involvement, number and size of liver lesions, histological diagnosis, presence of cirrhosis, type of hepatectomy, and associated procedures (excluding cholecystectomies). Collected data included patient characteristics and pre-, intra-, and postoperative variables up to 30 days after liver resection from nine high-volume centers (≥20 MIS procedures/year) and 11 low-volume centers.

The results highlight a continuous increase in the proportion of robotic liver surgery from 2014 to 2022, from 2% to 41.3% of MIS procedures. In contrast, after reaching 95% of MIS procedures in 2017, the proportion of laparoscopic surgery declined to 58.7% in 2022. Resection indications in both groups consisted predominantly of liver metastases, followed by benign pathologies and hepatocellular carcinoma.

Pre-propensity score matching analysis revealed significant heterogeneity between groups, with the laparoscopic group mainly consisting of multi-lesion resections and extrahepatic lesion resections, while the robotic group had significantly more major (i.e., ≥3 segments) and technically complex resections, defined as minor hepatectomies (<3 segments)

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in segments 1, 4a, 7, or 8, considered more challenging. Results from outcomes analysis favored the robotic approach, demonstrating significantly lower intraoperative blood loss (median: 100 *vs.* 180 mL, P=0.003), reduced conversion rates (4.9% *vs.* 13.5%, P<0.001), and shorter hospital stays (median: 3 *vs.* 4 days, P<0.001) compared to the laparoscopic approach.

After propensity score matching, the robotic and laparoscopic groups (n=781 patients each) were comparable in terms of matched variables. Intraoperative data analysis showed that the robotic approach resulted in significantly reduced massive blood loss volumes (i.e., ≥500 mL; 18.6% *vs.* 25.2%, P=0.011), conversion rates (4.9% *vs.* 12.8%, P<0.001), and length of hospital stay (3 *vs.* 4 days, P<0.001). Postoperative complication rates (Clavien-Dindo classification) and histological outcomes were similar between the two MIS approaches.

Several subgroup analyses were conducted. After excluding conversions, the robotic approach had significantly lower reoperation rates (1.1% *vs.* 2.7%, P=0.038). Sensitivity analysis confirmed the robotic advantage for minor and technically complex hepatectomies after excluding extrahepatic resections (n=688 per group). Excluding the learning curve period, results from the primary analysis were confirmed for surgeries between 2019 and 2022 (n=669 per group) except for the length of hospital stay, which was similar between groups (3 days, P=0.053). In high-volume centers, robotic resections were associated with lower blood loss (100 *vs.* 200 mL, P<0.001), fewer massive blood losses (17.9% *vs.* 25.6%, P=0.007), and reduced conversion rates (3.6% *vs.* 11.7%, P<0.001), but with similar length of hospital stay (4 days, P=0.596) compared with the laparoscopic approach.

Comments

This retrospective multicenter study, based on data from the Dutch national prospective database, underscores the advantages of robotic surgery as an emerging and growing surgical approach. Over the past two decades, robotic surgery has grown significantly, particularly in hepatopancreatobiliary (HPB) surgery, aligning with the findings of this study and international trends (3). The authors' study design is noteworthy for several reasons: (I) prospective data collection within a national database involving 20 centers and 3,530 patients; (II) robust statistical methods using propensity score matching and sensitivity analyses; (III) real-world reproducibility in both high- and low-volume centers; (IV) exclusion of liver surgeries prone to bias (e.g., fenestration, emergency surgery); and (V) clinically relevant analyzed variables.

After propensity score matching, significant superiority of the robotic approach was observed for minor and technically complex liver resections, particularly in terms of overall blood loss, massive bleeding, conversion rates, and lengths of hospital stay. These findings align with those of previous studies by Hu *et al.* (4) and Krenzien *et al.* (5), which reported reduced intraoperative blood losses and lower conversion rates for minor resections in posterior and anterior segments. However, the study by Pilz da Cunha *et al.* (1) did not consider resection difficulty using the IWATE score (6) due to database constraints. There were no significant differences in outcomes observed for major hepatectomies which are highly standardized in laparoscopy (7), aligning with previous literature (8), although this finding is limited by a small sample size in this subgroup. In contrast, the international multicenter study by Liu *et al.* (9), which included 892 major hepatectomies, demonstrated an advantage of the robotic approach in terms of length of hospital stay (6.1 *vs.* 7 days, P=0.002), although this difference was non-significant (P=0.61) with coarsened-exact matching. These inconsistent results warrant further investigations to validate the clinical benefits of robotic surgery for major hepatectomies. The robotic approach has also shown similar oncological outcomes compared to open and laparoscopic approaches (10), as evidenced by the similar R0 resection rates in both groups of this study.

Complex surgical procedures, such as resections of the superior and posterior segments (11), may be performed more easily with the robotic approach due to improved ergonomics, including articulated arms with seven degrees of freedom, potentially resulting in lower conversion rates. This observation is consistent with results from the sensitivity analysis in subgroups undergoing minor and technically complex hepatectomies (1).

The robotic approach remains poorly standardized, with potential biases stemming from technical reproducibility challenges (e.g., varied parenchymal dissection instruments) and logistical constraints (e.g., unequal robot access, different robotic systems) as described by the authors. Operator experience plays a significant role, with the authors suggesting thresholds of 50 laparoscopic and 25 robotic procedures per center to ensure surgical safety. However, these thresholds, which remain controversial in the literature (12), may be more appropriate to set at the operator rather than the center level. Only 9 of the 20

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centers were high-volume, which may suggest a dynamic heterogeneity among centers due to ongoing learning curves throughout the study period. Operator-level biases are also likely, as the number of trained personnel and the use of robotics in non-liver surgeries may vary between centers. Additionally, 40% of centers began performing laparoscopic surgery early in the study period, potentially introducing center-dependent and operator-dependent heterogeneity.

Despite these limitations, the heterogeneity among centers provides a real-world perspective. Recent international studies evaluating robotic surgery (4,9,13) have primarily been conducted in high-volume HPB centers with their expertise often linked to liver transplantation. Operators in expert centers typically have enhanced experience, optimizing study outcomes. The study by Pilz da Cunha *et al.* (1) includes operators with heterogeneous expertise levels in HPB surgery, making it representative of real-world national outcomes. In this context, increasing national implementation of robotic approaches could potentially benefit patients while maintaining financial balance.

The lower postoperative complication (Clavien-Dindo score at 30 days), reoperation, and readmission rates as well as shorter lengths of hospital stays (1), suggest a financial advantage of robotic approaches in addition to improved patient outcomes (14). Conversion to open surgery is associated with unfavorable prognostic impacts (15) and increased financial costs (16), mainly attributed to extended lengths of hospital stay. Evaluating the financial benefits of robotic hepatectomy would require taking into consideration key factors such as hospitalization duration, complication rates, postoperative recovery, readmission rates, and quality of life. A study with this primary endpoint would be valuable.

In conclusion, this nationwide, multicenter study sheds light on the real-world application of robotic liver surgery, highlighting its growing adoption and clinical advantages. The robust study design and the inclusion of data from centers with varying levels of expertise make these findings highly representative of real-world clinical practice. Moreover, this study emphasizes significant advantages of robotic surgery in terms of reducing blood losses and conversion rates for liver resections, with reduced lengths of hospital stays for minor and technically complex resections. Future studies are required to evaluate long-term outcomes, cost-effectiveness, and quality of life to further validate and optimize the beneficial role of robotics in liver surgery.

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