Development Process and Technical Aspects of Laparoscopic Hepatectomy: Learning Curve Based on 15 Years of Experience

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BACKGROUND: Laparoscopic hepatectomy continues to be a challenging operation associated with a steep learning curve. This study aimed to evaluate the learning process during 15 years of experience with laparoscopic hepatectomy and to identify approaches to standardization of this procedure.

STUDY DESIGN: Prospectively collected data of 317 consecutive laparoscopic hepatectomies performed from January 2000 to December 2014 were reviewed retrospectively. The operative procedures were classified into 4 categories (minor hepatectomy, left lateral sectionectomy [LLS], left hepatectomy, and right hepatectomy), and indications were classified into 5 categories (benign-borderline tumor, living donor, metastatic liver tumor, biliary malignancy, and hepatocellular carcinoma).

RESULTS: During the first 10 years, the procedures were limited mainly to minor hepatectomy and LLS, and the indications were limited to benign-borderline tumor and living donor. Implementation of major hepatectomy rapidly increased the proportion of malignant tumors, especially hepatocellular carcinoma, starting from 2011. Conversion rates decreased with experience for LLS (13.3% vs 3.4%; $p = 0.054$) and left hepatectomy (50.0% vs 15.0%; $p = 0.012$), but not for right hepatectomy (41.4% vs 35.7%; $p = 0.661$).

CONCLUSIONS: Our 15-year experience clearly demonstrates the stepwise procedural evolution from LLS through left hepatectomy to right hepatectomy, as well as the trend in indications from benign-borderline tumor/living donor to malignant tumors. In contrast to LLS and left hepatectomy, a learning curve was not observed for right hepatectomy. The ongoing development process can contribute to faster standardization necessary for future advances in laparoscopic hepatectomy. (J Am Coll Surg 2017;224:841−850. © 2017 by the American College of Surgeons. Published by Elsevier Inc. All rights reserved.)

With advances in instrument technology and surgeon experience, laparoscopic surgery has gained global acceptance for several abdominal surgical procedures. However, laparoscopic hepatectomy has not been as widely adopted as other surgical techniques.[1] Barriers to implementation of laparoscopic hepatectomy include the anatomical complexity of the liver, the proximity of large vascular structures, and technical difficulty.[2,3] In addition, hepatectomy is less common and, in addition, does not constitute a single procedure, with vast differences in complexity between such procedures as wedge resection and major hepatectomies involving anatomical resection of 3 or more segments. This makes it more difficult to develop the approach and overcome the hurdles associated with the steep learning curve of laparoscopic hepatectomy, which continues to be a challenging operation.[3,4]

The laparoscopic approach to left lateral sectionectomy (LLS) in a living donor (LD) was first proposed by our team in 2002,[5] and its safety and reproducibility were demonstrated in 2006 in a comparative study.[6] In

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Abbreviations and Acronyms

ASA = American Society of Anesthesiologists
BBT = benign-borderline tumor
HCC = hepatocellular carcinoma
LD = living donor
LLS = left lateral sectionectomy
PVE = portal vein embolization

addition, in 2014, we successfully transferred this technique from the phase of innovation to the phase of development.[7] This long development process could be related to the learning curve in which technical refinements improve outcomes.[8-11] Herein we embark on a study reviewing our experience with laparoscopic hepatectomy accumulated in the course of 15 years that have passed since its first application, with a special focus on the time trends of procedures and indications. This study aimed to identify the ways of efficient standardization of this procedure, especially when progressing from the left side of the liver to its right side.

METHODS

Patient characteristics and study design

The prospectively collected data for 317 consecutive laparoscopic hepatectomies performed by our team during the 15 years from January 2000 to December 2014 were retrospectively reviewed. The team includes 2 senior surgeons, and 1 or both of them are required to join each operation. The procedures were classified into 4 categories: minor hepatectomy, LLS, left hepatectomy, and right hepatectomy. Preoperative indications were classified into 5 categories: benign-borderline tumor ([BBT]; eg focal nodular hyperplasia, hemangioma, adenoma, hemangioendothelioma, hydatid cyst), LD, metastatic liver tumor, biliary malignancy, and hepatocellular carcinoma (HCC). Patient charts were retrospectively reviewed for history and demographics, liver pathology, and intraoperative, as well as postoperative outcomes. Postoperative complications were also graded according to the Clavien-Dindo classification,[12] and major complications were defined as a Clavien-Dindo classification grade III or higher. The preoperative factors (age, sex, BMI, American Society of Anesthesiologists [ASA] score, indication for the treatment), operative factors (operative procedure, operative time, blood loss, transfusion requirement, pedicle clamping, conversion), and postoperative factors (mortality, morbidity, and hospital stay) were examined. Time trends for procedures and indications for laparoscopic hepatectomy during the study period were evaluated chronologically.

The learning curve analysis was based on the conversion rate. Accordingly, for each laparoscopic procedure, the clinical outcomes were compared between patients who underwent surgery earlier and later in the study period. The current study was conducted according to the Helsinki Declaration, and written informed consent was obtained from all patients.

Criteria of patient selection and conversion of laparoscopic hepatectomy

Because indications for laparoscopic surgery continued to evolve during the study period, it might seem difficult to formalize them clearly. The absolute exclusion criteria for laparoscopic hepatectomy throughout the time period analyzed were as follows: spread to other organs; difficulty in identifying an adequate tumor margin, which included cases associated with tumor thrombus invasion into the major hepatic or portal veins (main or first branch); and history of open hepatectomy. At the outset, we decided that any incident that might compromise patient safety should lead to prompt conversion. We defined such events, or criteria for conversion, as follows: substantial bleeding, failure to determine bile duct anatomy precisely, any vessel injury, and poor exposure leading to failure or slow progress during parenchymal transection.

Technical aspects of laparoscopic hepatectomy

Installation and trocar positioning

The patient is placed in a supine position with split legs (French position), with the surgeon standing between the legs and assistants on either side. Devices to prevent hypothermia (warming coverage) and deep vein thrombosis (compression stockings) are used routinely. Two monitors are placed above the left and right patient's shoulders. A 30-degree laparoscope or flexible endoscope is used, and a carbon dioxide pneumoperitoneum is created and maintained at a pressure of 12 mmHg. The first trocar is placed 2 to 3 cm above the umbilicus through a 12-mm incision at this site to be used as the camera port. Two additional 12-mm trocars are placed, 1 laterally and 1 medially to the camera port, and 2 additional 5-mm trocars are placed. Trocars are designed to be placed in the median to right subcostal incision. We use only 2 patterns of trocar positioning, depending on the tumor location (left or right side from Cantlie's line), as shown in Figure 1A and B.

Basic principles of laparoscopic hepatectomy

Tape is routinely encircled around the hepatoduodenal ligament using a tourniquet to prepare for inflow occlusion (Pringle maneuver; Video 1). The Harmonic Scalpel (Ethicon Endo-Surgery, Inc) or Thunderbeat (Olympus)