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Review Article

Current status of robotic surgery for liver transplantation

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A B S T R A C T

Successfully performing laparoscopic procedures in donor hepatectomy provides better quality of life and minimizes surgical complications for the donor. However, only a few experienced institutions can perform laparoscopic donor hepatectomy, which has a long learning curve and unergonomic surgical conditions. Meanwhile, robotic surgical systems have advanced to the point that they can compensate for the limitations of laparoscopic surgical systems. A robotic system provides a steady and magnified three-dimensional visualization with a wide range of motion and tremor-free instrumentation. Due to the benefits of robotic systems, robotic donor hepatectomy has been successfully performed in recent years. Therefore, the aim of this review is to present the current circumstances regarding the use of robotic systems in liver transplantation.

Keywords: Hepatectomy; Liver transplantation; Robot surgery

Introduction

Enormous progress and achievements have been made in the field of liver surgery over the last 5 decades. Until the late 1970s, the mortality rate after liver resection due to intraoperative and postoperative bleeding was very high, exceeding 15%.[1] However, due to developments in liver resection technology, advances in our understanding of the anatomy and physiology of the liver, developments in anesthesia, and improvements in perioperative patient management, the post-hepatectomy mortality rate at experienced tertiary hospitals has decreased to around 1%. In the meantime, liver transplantation, which was first performed by Thomas Starzl in 1963, has made substantial progress in both technical and academic aspects. Living donor liver transplantation (LDLT), which was first attempted in 1988 to solve the organ shortage problem, has become one of the mainstays of liver transplantation.[2,3] Extensive global experience with LDLT has been gathered, considering not only the donor's safety but also the quality of life. Studies on the operative outcomes of living donor hepatectomy have reported mortality rates of 0.2% to 0.6% and overall morbidity rates of 20% to 40%.[4–6] Most complications with open living donor hepatectomy are associated with the operative approach, with manifestations such as incisional pain, surgical site infection, disfiguring scars, incisional hernia, and adhesive intestinal obstructions. Laparoscopic liver resection has been performed to overcome the shortcomings of open liver surgery. Cherqui et al[7] reported laparoscopic donor left lateral sectionectomy for pediatric liver transplantation in 2002. Since Han et al[8] reported the first right-side pure laparoscopic donor hepatectomy in 2010, laparoscopic procedures have been widely performed in the field of living donor hepatectomy worldwide. However, due to the inherent limitations of laparoscopy, such as unergonomic instrumentation and a longer learning curve, pure laparoscopic procedures for liver transplantation are limited to a few experienced institutions. In recent years, robotic systems have been developed to overcome the limitations of laparoscopy.[9]

The Current Status of Robotic Surgery in the Liver Transplant Field

Robotic surgery for the donor in LDLT

Giulianotti et al[10] from Chicago reported the first successful right lobe donor hepatectomy in 2012. Subsequently, several pure robotic donor hepatectomies have been reported globally, from countries including Korea, Taiwan, and Saudi Arabia.[11–15]

The difficulties of unsteady visualization and suboptimal instrumentation from the limited degrees of freedom are intrinsic obstacles to laparoscopic donor hepatectomy. In contrast to laparoscopic systems, robotic platforms provide steady visualization

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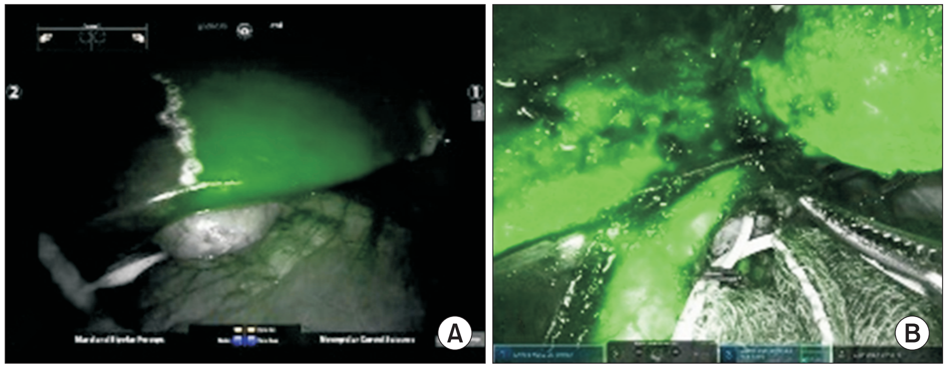

Fig. 1. Fluorescence-guided image using indocyanine green in robotic donor hepatectomy. (A) The ischemic demarcation line after temporary clamping of the right hepatic artery and portal vein in robotic donor right hemihepatectomy. (B) Indocyanine green fluorescent cholangiography in robotic donor left hemihepatectomy.

with a magnified 3-dimensional view and tremor-free instrumental movement with wider range of angulation. Therefore, the ability to perform suturing more easily and more efficiently may enable a longer vascular stump and proper bile duct opening of the graft.[14,16–20] Moreover, surgical navigation with Firefly indocyanine green imaging facilitates precise parenchymal anatomic dissection, as well as exact division of the bile duct (Fig. 1).

The learning curve for pure laparoscopic donor hemihepatectomy is 45 to 60 cases for an experienced transplant-laparoscopic surgeon.[21–24] However, the learning curve for robotic donor hepatectomy was reported to be 15 cases.[12,13] More importantly, a prior knowledge of laparoscopic surgery is not an absolute prerequisite for initiating a robot donor hepatectomy program.[25] According to a prospective multicenter pilot study, robotic anatomic major liver resection can be safely performed by robotic beginners who are advanced open and laparoscopic liver surgeons.[26]

According to a meta-analysis of 2,728 cases of robotic liver surgery, the operative complication rate was lower in robotic liver surgery than in open liver resection. Although the complication rates of robotic liver resection and laparoscopic liver resection were comparable, the complication rate was lower in robotic major liver resection than in laparoscopic major liver resection. The postoperative hospital stay was shorter after robotic liver resection than after open liver resection. However, the operative time and cost of robotic liver resection were inferior to those of both laparoscopic and open liver resection.[27]

Robotic surgery for the recipient in LDLT

Although a robotic system provides an efficient suturing technique under the magnified steady visualization, robotic surgery has rarely been applied to recipient surgery in LDLT due to the safety and technical difficulty. In general, the presence of many collaterals owing to the cirrhotic condition of the recipient makes it difficult to perform prompt control in minimally invasive surgery.[28] Despite these difficulties, minimally invasive approaches to the recipient in LDLT were recently successfully reported by Lee et al[29] and Suh et al.[30] Lee et al[29] explanted the recipient liver laparoscopically and implanted the graft with a robotic system. Suh et al[30] also explanted the recipient liver laparoscopically, and reconstructed the hepatic and portal veins using the laparoscopic approach to shorten the ischemic time. They then applied the robotic system to perform anastomosis of the hepatic artery and bile duct. However, the operative time and ischemic time more than doubled. In particular, a longer ischemic time and operative time may have a potential negative impact on graft survival and on the postoperative recovery of the recipient, who is in a medically very vulnerable condition. Therefore, the surgical indications of minimally invasive recipient surgery should be carefully considered.

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Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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