Introduction: The Importance of Ultrasound in a Surgical Practice

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Kevin Ryan Parks and Ellen J. Hagopian

Introduction

The surgeon relies heavily on diagnostics and imaging in addition to history and physical exam when evaluating a patient's clinical picture. Decisions based on this information are constantly under review and rereview. Information available is often the result of the surgeon's own practices and choices, such as where and how to palpate, and leads to information that can improve the outcome of the case, whether it means arriving at a diagnosis or an operative decision. Because of its diagnostic accuracy, intraoperative ultrasound has been a tool of the abdominal surgeon for a number of years. Intraoperative ultrasound (IOUS) allows the unseen to be seen and has been recognized as a vital component in many surgical procedures. This chapter will review the history and role of IOUS in abdominal surgery and will consider some of the challenges and eventual rewards when incorporating ultrasound into a surgical practice.

Brief History of Surgical Ultrasound

Although the use of intraoperative radiology, such as intraoperative cholangiography, began in the 1930s, the first use of intraoperative ultrasound was not until the early 1960s. Early use of ultrasound in the operating room utilized A-mode imaging (see Chap. 2), which consisted of one-dimensional amplitude spikes on a display screen. Schlegel and colleagues [1] introduced A-mode ultrasound to locate renal calculi during nephrolithotomy in 1961. Following this, other investigators used ultrasound in the operating room to locate biliary stones. The initial clinical report was by Hayashi and colleagues [2], followed by Knight and Newell [3]. Despite these reports, the use of ultrasound in the operating room did not gain widespread acceptance due to challenges in understanding and interpreting A-mode imaging.

By the 1970s, A-mode imaging had given way to the development of real-time brightness, or B-mode, imaging (see Chap. 2), which is the more familiar ultrasound used today. This refined imaging overcame the difficulties of previous technologies, given its real-time and two-dimensional image advantages. The initial reports of this ultrasound technology were in the mid- to late 1970s, when Cook and Lytton [4] reported the intraoperative detection of renal calculi and Makuuchi et al. [5] reported the intraoperative localization of liver tumors. The less-complicated image interpretation of this B-mode imaging led to A renewed interest in intraoperative ultrasound. Despite this, acceptance of intraoperative ultrasound was still slow in the 1980s.

In 1989, Machi and Sigel reported a 10-year experience in operative ultrasound during 2,299 abdominal (including liver, pancreas, biliary, gastrointestinal, kidney), thoracic, cardiovascular, neurologic, and endocrine operations [6]. Intraoperative ultrasound was deemed useful in 91.5 % of cases. In a subsequent report, Machi and colleagues wrote specifically on their experience in 357 hepatic, 735 biliary, and 242 pancreatic cases [7]. In this follow-up report, they found the sensitivity, specificity, and accuracy in diagnosing colorectal liver metastases to be 93, 95, and 94 %, respectively, and in diagnosing common bile duct stones to be 92, 99, and 99 %, respectively. Furthermore, intraoperative ultrasound of the pancreas was found to be beneficial in 73 %. With increasing numbers of reports focusing on the advantages and benefits of intraoperative ultrasound, such as those by Machi and Sigel [6, 7], the use

K.R. Parks, BA
Department of Surgery, Jersey Shore University Medical Center, Neptune, NJ, USA

Department of Surgery, Robert Wood Johnson Medical School, New Brunswick, NJ, USA
e-mail: parkskr@umdnj.edu

E.J. Hagopian, MD, FACS (✉)
Department of Surgery, Jersey Shore University Medical Center, Neptune, NJ, USA

Department of Surgery, Robert Wood Johnson Medical School, New Brunswick, NJ, USA

Department of Surgery, New York Medical College, Valhalla, NY, USA
e-mail: ellenhagopian@aol.com

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of ultrasound became more widespread and accepted. By the mid-1990s, surgeons had recognized the value of ultrasound during certain procedures and real-time B-mode imaging was applied routinely for various operations including liver, biliary, pancreatic, endocrine, and vascular surgeries. Even with the improvement of preoperative imaging in the new millennium, such as multidetector computed tomography and magnetic resonance imaging, intraoperative ultrasound remains a necessary and indispensable tool of the abdominal surgeon [8–15].

Training in Surgical Ultrasound

Realizing the value of surgical ultrasound is fundamental to motivating the surgeon to train for proficiency in performing, interpreting, and utilizing ultrasound in practice. While the challenge of training on a different imaging modality may seem formidable, it should be recognized that this situation is in no way unique. Surgeons routinely use techniques that require special training and time to master. Although the learning curve in ultrasound may appear steep, a surgeon's knowledge of three-dimensional anatomy enables his/her understanding of ultrasound images and thus the slope of the curve is lessened.

The main obstacle to overcome in incorporating ultrasound into a surgical practice is the difficulty in obtaining sufficient training in ultrasound. For those in training, ultrasound may be integrated within surgical residency and fellowship programs. However, for surgeons in practice, a formalized curriculum and consistent practice are paramount. Formalized training in surgical ultrasound can be obtained through the American College of Surgeons and, most recently, through the Americas Hepato-Pancreato-Biliary Association. Practical application following observational experience is extremely important to gaining skill in ultrasound. According to Machi and Sigel with their colleagues, the learning curve for intraoperative ultrasound depends on the purpose of intraoperative ultrasound, the target organ of interest, and the complexity of the imaging procedure [7]. They suggest that about 25 ultrasound examinations are required to overcome the learning curve for screening for colorectal liver metastases. Similarly, about 25 examinations are required for screening for bile duct stones. As ultrasound guidance procedures require two-handed skill, a greater number of examinations are needed. For ultrasound guidance operations, for example, about 25–40 pancreas and 50 liver examinations/procedures are needed. In Chap. 20, training issues are reviewed in detail.

Surgical Ultrasound in Practice

Incorporating ultrasound into a surgical practice has significant rewards, not only in terms of patient benefit and patient outcome but also in terms of surgical professional development.

Clinical Evaluation: Extension of the Physical Exam

Ultrasound can be used as an extension of the physical exam of the patient. In the same way that a stethoscope extends the auditory examination of the lungs and other organ systems, ultrasound extends the examination of the abdomen. Because of its dynamic and instantaneous nature, ultrasound has inherent advantages over other imaging modalities. One of the best examples of this use of ultrasound at the bedside is in trauma. In the trauma bay, ultrasound is routinely used as part of the physical exam to guide clinical decision-making.

Intraoperative Evaluation

Hepatic Resection

The use of ultrasound in the operating room can be viewed as an extension of the physical exam but is also essential to the localization of abnormalities and the planning, guiding, and ensuring of the completeness of surgery. Hepatic surgery is perhaps the clearest example of the surgical applications of intraoperative ultrasound. The dynamic nature of ultrasound imaging provides clear pictures of blood vessel variations, segmental anatomy, and the localization of not only known but also occult tumor(s) that might otherwise be unknown to the surgeon. Recognizing variations in portal venous and hepatic venous anatomy is critical in liver surgery. Intraoperative ultrasound can identify the presence of clinically significant abnormalities, which can help to guide the operation. For example, a significant percentage of patients have variations in both the number and organization of hepatic veins. An inferior right hepatic vein is found in 10–15 % of patients, which drains directly into the inferior vena cava caudal to the right hepatic vein. The presence of this accessory hepatic vein allows resection of segment 7 with the right hepatic vein, while allowing for preservation of segment 6. Less common are variations in the portal venous anatomy. One variation is the absence of the main right portal vein where the main portal vein divides into three veins: the right anterior, the right posterior, and the main left portal vein [16].

While identifying variations in vascular anatomy, the surgeon can also define the segmental anatomy and localize lesions. Furthermore, with its diagnostic accuracy, occult lesions not visualized on preoperative imaging can be defined. By clearly defining the extent of disease, resectability can be determined by the surgeon in the operating room. Following resection, IOUS can be utilized to ensure completeness of resection. Knowledge of anatomy is important to surgery, but knowledge of a particular patient's anatomy and extent of disease is paramount to planning liver resection and guiding surgery once it has begun.

Staging of Malignancy

The utility of ultrasound in abdominal surgery is also applied to staging of the extent of disease in many intra-abdominal malignancies. Preoperative staging of rectal cancer can be accomplished with transrectal endoluminal ultrasound and the extent of a pancreatic tumor can be evaluated using endoscopic ultrasound. Intraoperative ultrasound can also be integrated into the staging of pancreatic, gastric, and colorectal cancers while evaluating local disease and the presence of liver metastases [17]. Especially when combined with laparoscopy, intraoperative (laparoscopic) ultrasound can be instrumental in salvaging the patient from unnecessary laparotomy if occult metastatic disease is found.

Guidance of Procedures

Ultrasound can be used to guide operative procedures. Not only can ultrasound be used to target a liver lesion for biopsy or ablation, it can also be used to guide cannulation of the pancreatic duct. Minimally invasive approaches, such as percutaneous or laparoscopic techniques, utilize ultrasound in abdominal abscess drainage and have been recognized as a safe alternative therapy to open surgery [18]. Common bile duct stones can be identified during open or laparoscopic ultrasound to determine the need for common bile duct exploration or endoscopic retrieval. Furthermore, intraoperative ultrasound is essential for hepatectomy prior to resection by marking vasculature, during resection by guiding the line of parenchymal resection, and following resection by ensuring completion of resection.

Professional Development

It may be clear that utilization of ultrasound in a surgical practice is in the best interest of the patient, but it should be equally understood that using and understanding ultrasound are in the best interest of the surgical profession. Surgical ultrasound has had time to grow and refine as a technology and will continue to be introduced into procedures and practices not yet considered. Advances in technology will continuously influence surgical procedures. Less invasive surgery, such as laparoscopic liver resection and robotic-assisted pancreatoduodenectomy, displaces the surgeon's hand from the operation and thus increases the need for image guidance, such as what is provided for by ultrasound. As surgery evolves, new uses of ultrasound can be developed to continue to address the changing needs of the surgeon in the operating room. Newer technologies in ultrasound are reviewed in Chap. 23.

Our understanding and use of ultrasound in the daily practice of surgery are important when teaching the skill of surgery. For future surgeons, the understanding of how and when to utilize ultrasound in surgery becomes more imperative as new uses of this indispensible tool are developed.

Conclusion

Intraoperative ultrasound is an extremely useful tool for the surgeon, which demands presence at the forefront of patient care. In its beginnings, ultrasound was used primarily as a diagnostic tool but now has evolved to include multiple uses. Used not only in the mere diagnosis of conditions, but surgical ultrasound is also often used as an extension of the physical exam at the bedside and operating room in addition to use in surgical therapeutic procedures. Incorporating ultrasound into a surgical practice has significant rewards, not only in terms of patient benefit and outcome but also in terms of development of the surgical profession.

References

1. Schlegel JU, Diggdon P, Cuellar J. The use of ultrasound for localizing renal calculi. J Urol. 1961;86:367–9.
2. Hayashi S, Wagai T, Miyazawa R, Ito K, Ishikawa S, Uematsu K, Kikuchi Y, Uchida R. Ultrasonic diagnosis of breast tumor and cholelithiasis. West J Surg Obstet Gynecol. 1962;70:34–40.
3. Knight PR, Newell JA. Operative use of ultrasonics in cholelithiasis. Lancet. 1963;1(7289):1023–5.
4. Cook 3rd JH, Lytton B. Intraoperative localization of renal calculi during nephrolithotomy by ultrasound scanning. J Urol. 1977;117(5):543–6.
5. Makuuchi M, Torzilli G, Machi J. History of intraoperative ultrasound. Ultrasound Med Biol. 1998;24(9):1229–42.
6. Machi J, Sigel B. Overview of benefits of operative ultrasonography during a ten year period. J Ultrasound Med. 1989;8:647–52.
7. Machi J, Sigel B, Zaren HA, Kurohiji T, Yamashita Y. Operative ultrasonography during hepatobiliary and pancreatic surgery. World J Surg. 1993;17:640–6.
8. Lordan JT, Stenson KM, Karanjia ND. The value of intraoperative ultrasound and preoperative imaging, individually and in combination, in liver resection for metastatic colorectal cancer. Ann R Coll Surg Engl. 2011;93(3):246–9.
9. Sietses C, Meijerink MR, Meijer S, van den Tol MP. The impact of intraoperative ultrasonography on the surgical treatment of patients with colorectal liver metastases. Surg Endosc. 2010;24(8):1917–22.
10. Conlon R, Jacobs M, Dasgupta D, Lodge JP. The value of intraoperative ultrasound during hepatic resection compared with improved preoperative magnetic resonance imaging. Eur J Ultrasound. 2003;16(3):211–6.
11. D'Onofrio M, Gallotti A, Martone E, Nicoli L, Mautone S, Ruzzenente A, Mucelli RP. Is intraoperative ultrasound (IOUS) still useful for the detection of liver metastases? J Ultrasound. 2009;12(4):144–7.
12. Shukla PJ, Pandey D, Rao PP, Shrikhande SV, Thakur MH, Arya S, Ramani S, Mehta S, Mohandas KM. Impact of intra-operative ultrasonography in liver surgery. Indian J Gastroenterol. 2005;24(2):62–5.
13. Skrovina M, Bartos J, Cech B, Velkoborsky M, Czudek S, Kycina R, Bartos P, Adamcík L, Konvicna R, Soumarova R. Intra-operative liver ultrasound–a contribution to colorectal carcinoma staging. Acta Chir Belg. 2008;108(5):508–12.
14. Thaler K, Kanneganti S, Khajanchee Y, Wilson C, Swanstrom L, Hansen PD. The evolving role of staging laparoscopy in the treatment of colorectal hepatic metastasis. Arch Surg. 2005;140(8):727–34.
15. D'Hondt M, Vandenbroucke-Menu F, Préville-Ratelle S, Turcotte S, Chagnon M, Plasse M, Létourneau R, Dagenais M, Roy A, Lapointe R. Is intra-operative ultrasound still useful for the

detection of a hepatic tumour in the era of modern pre-operative imaging? HPB (Oxford). 2011;13(9):665–9.
16. Fang CH, You JH, Lau WY, Lai EC, Fan YF, Zhong SZ, Li KX, Chen ZX, Su ZH, Bao SS. Anatomical variations of hepatic veins: three-dimensional computed tomography scans of 200 subjects. World J Surg. 2012;36(1):120–4.
17. Machi J, Takeda J, Kakegawa T, Yamana H, Fujita H, Kurohiji T, Yamashita Y. The detection of gastric and esophageal tumor extension by high-resolution ultrasound during surgery. World J Surg. 1987;11(5):664–71.
18. Men S, Akhan O, Köroğlu M. Percutaneous drainage of abdominal abscess. Eur J Radiol. 2002;43(3):204–18.