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## Editorial

## The Janus of mIS in hepatobiliary surgery: Importance of maximally invasive surgery in an era of minimally invasive surgery

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As surgeons formidably continue to forge into the twenty-twenties, after a considerably coronavirus-induced rocky start, one can predict that the era of minimally invasive surgery (mIS), an era of robotics, telehealth, and enhanced recovery after surgery (ERAS®), is not only here to stay but will continue to thrive, develop, and transform our practices. Critics of robotics platforms would be hard pressed not to indulge in this prediction. Will the satisfyingly large midline “stem to stern”, the impressing exposure-generating Makuuchi or transverse abdominal, the Kocher, paramedian, McBurney, Chevron, and Pfannenstiel incisions begin to disappear and fade away into a scar minimizing future precluding trauma laparotomies? Most likely not. Understanding and developing the skill and technique for a minimally invasive “mIS” approach does not negate or abrogate the maximally invasive “MIS” ones. It is not one or the other; not a “to be or not to be” Shakespearean scenario. Hepatobiliary surgery is a qualified landscape upon which to illuminate and exemplify this declaration: the necessity and companionship of “mIS” and “MIS” – minimally and maximally invasive surgery.

The Hepatobiliary Surgery Department at Atrium Health-Carolinas Medical Center (AH-CMC) is well-known for not only forging but maintaining the front lines of minimally invasive hepatobiliary surgery. Beginning with the development of laparoscopic ablative modalities, we have created one of the world’s largest microwave databases with over 1000 surgical ablations performed in the last 15 years, using our experience to offer insight into patient selection, approach, technique and oncologic efficiency [1]. Our laboratory further continues to propel ablation forward, overcoming limitations and advancing performance with novel adjustments and devices [2]. In the same time frame, we have performed over 1500 pancreatic resections and 1100 hepatectomies of which 40% and over 70% are done through a minimally invasive approach, respectively. Our utilization of the robotic platform parallels our laparoscopic experience, with 30% of our pancreaticoduodenectomies being performed robotically, setting standards in operative and oncologic outcomes [3]. With such a considerable minimally invasive application and prominence, one would imagine that maximally

invasive techniques and innovations would take a back seat along with a strong patient selection bias; however, this is not the case. First, the concept of MIS needs to be defined. We define maximally invasive hepatobiliary surgery as having two distinct domains: (i) liver molding strategies and (ii) vascular resections and reconstructions.

Liver molding is a strategy to modulate or “grow” portions of the liver to obtain a free of malignant tumor burden future liver remnant (FLR) that will be compatible with life after liver resection. A too small FLR creates risk for postoperative liver failure, precluding immediate liver resection. With controversy surrounding the variable entrance of the following players, the regenerative options range from portal vein embolization or ligation, liver venous deprivation and radiation lobectomy to staged hepatectomies and associating liver partition and portal vein ligation for staged hepatectomy (ALPPS) procedure [4]. Our experience of over 60 trisectionectomies that required pre-hepatectomy FLR manipulation has given us considerable insight into liver molding techniques and their oncologic efficiency as well as patient’s Return to Intended Oncologic Treatment (RIOT). While currently fading to the wayside, ALPPS initially expanded our armamentarium for extensive liver resections by accelerating FLR hypertrophy with decreased time interval between stages and as a salvage strategy when portal vein embolization demonstrated inadequacy. AH-CMC is one of the few USA centers to perform this “maximally-invasive” approach within the limits of the ALPPS international registry; and, ironically, AH-CMC is also the first center to perform the first robotic “mIS” ALPPS. However, the upsurge of passion that accompanied the introduction of ALPPS began to wane as registry results demonstrated high morbidity and significant mortality rates initially. Now, combined portal vein embolization and hepatic vein embolization have replaced ALPPS in our molding algorithm and may mark the newest on our FLR augmentation frontier; outcome analysis is ongoing.

Vascular resections and reconstructions are the other class of maximally invasive hepatobiliary techniques subdivided into normothermic and hypothermic resections. Over the last ten years, our department has performed over 50 normothermic venous hepatobiliary resections [5]. No matter whether it is tumorous invasion of the portal vein or thrombus located within the inferior vena

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cava (IVC), the modern minimally invasive hepatobiliary surgeon should also be able to perform an open oncologic operation with vascular resection and reconstruction. Knowing when to use primary repair, patch, or graft techniques of the IVC or the portal vein is an essential part of one's education and experience. Considerably more skill and risk involve when arterial resection is needed. Experienced hepatobiliary surgeons trending for laparoscopic and robotic innovation must be able to perform these technically demanding maximally invasive open procedures with favorable results, offering prolonged survival in highly selected patients [6]. This is mandatory for optimal and individualized patient care in a strong and innovative academic hepatobiliary center. As anesthetic technical approaches continue to improve in parallel, procedural feasibility will only further expand candidate pools and techniques must evolve and be mastered as surgeons strain maximally invasive boundaries.

Hypothermic vascular resections carry a rich history beginning in the 1960s in transplant literature [7]. Dissemination of Fortner's and Pichlmayer's work, shortly thereafter, took and altered these concepts, issuing *in-situ* and *ex-vivo* liver resection with the antecaval approach emerging several decades later [8–10]. This development and experience with orthotopic liver transplantation and *ex-vivo* split donor liver contributed to the techniques for *ex-vivo* resections. While still quite rare, hypothermic extracorporeal approaches render considerable heterogeneity with adoption of technique often resting in familiarity rather than data. Perfusion options vary from temporary reconstructions, shunts, to venovenous bypass; and, *in-situ* vascular reconstruction offers a similar amalgam of conduit selections. Regardless, while multi-institutional analyses are clearly needed, *ex-vivo* resections offer, for selected patients, opportunity for prolonged survival and potential cure. Our institution has performed seven hypothermic IVC resections when conventional techniques have been inadequate, altering the definition of resectability, making it oncologic rather than technical. For instance, when a patient was diagnosed with cholangiocarcinoma involving IVC and all three hepatic veins, conventionally far from resectable, the first combined application of ALPPS with an *ex-vivo* liver resection, after neoadjuvant chemotherapy, led to a successful R0 resection and a survival of 27 months at last follow-up [11].

Proficiency in maximally invasive hepatobiliary surgery necessitates a clear partnership and understanding of interventional radiology, anesthesiology and transplant surgery. Awareness and adoption of the strides made in transplant allow for expansion of curative interventions making a hepatobiliary surgeon a 'complete' surgeon. She or he must be accomplished and capable of not only laparoscopic ablations and robotic Whipple procedures but also of extended liver resections with molding and vascular involvement requiring understanding of hypothermic perfusion and extracorporeal techniques. Maximally invasive techniques should be inseparable from minimally invasive counterparts. One cannot forge forward in one and leave the other to perish else as it will limit the surgeon's abilities; for out of our experience of over 2000 liver cases over the last 15 years, maximally invasive techniques are required in approximately 5% of patients. Thus, to be considered a high-volume center, there is expectation that those 5% can capably be kept and handled. A fully-fledged expert hepatobiliary surgeon, in the modern era, must be a master of both the minimally and maximally invasive techniques, for there will always be patients, cases, tumors requiring an understanding of not only "mIS", but also "MIS".

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