Hydro-Jet Assisted Laparoscopic Cholecystectomy: Initial Experience in a Porcine Model

Hodjat Shekarriz, MD, Bijan Shekarriz, MD, Jyoti Upadhyay, MD, Andreas Comman, MD, Uwe Markert, MD, Conny G. Bürk, MD, Peter Kujath, MD, Hans-Peter Bruch, MD

ABSTRACT

Background and Objectives: Hydro-Jet technology has long been used for cutting various materials like metal and wood in the industrial field. In the medical field, this technology has been applied successfully for selective cutting of the parenchyma of the liver. However, to our knowledge, no data exist on the use of the Hydro-Jet technique for laparoscopic cholecystectomy. The purpose of this study was to evaluate a new dissection technique using a high-pressure water stream (Hydro-Jet) and a new dissection probe for laparoscopic cholecystectomy.

Methods: Thirty pigs underwent laparoscopic cholecystectomy. Pigs were randomized to receive either the conventional or Hydro-Jet assisted dissection technique. The feasibility of this technique and the features of surgical dissection were evaluated and compared between the 2 groups.

Results: Laparoscopic cholecystectomy was successful in all animals with no need for conversion to open surgery. The mean operative time was 28 and 36 minutes for Hydro-Jet versus conventional dissection, respectively. Complications using the Hydro-Jet and conventional techniques included 6% and 20% gallbladder perforation and 6.5% and 13% liver laceration, respectively. The use of the Hydro-Jet for cholecystectomy had clear technical advantages over conventional dissection. The Hydro-Jet resulted in a selective dissection of fibrous and connective tissue preserving blood vessels for later ligation. Therefore, the dissection was performed in a relatively bloodless field. The ease of dissection using the new bent tipped dissector represents another advantage. Finally, the continuous water flow allowed a clear view for the operator.

Conclusions: This study shows that Hydro-jet dissection represents an excellent alternative to the conventional technique for laparoscopic cholecystectomy. The improved anatomical dissection combined with an almost bloodless operating field secondary to continuous water flow may decrease dissection-related complications.

Key Words: Laparoscopy, Cholecystectomy, Hydro-Jet, Dissection, Animal.

INTRODUCTION

Laparoscopic cholecystectomy has become standard treatment today. Laparoscopy offers the advantage of being a less morbid procedure with shorter convalescence time compared with that of standard open surgery.1,2 However, complications may occur. In large European and United State series, complications included bleeding (0.2% to 4.3%), bile duct injuries (0.2% to 1%), and bile duct fistulas (0.2% to 1%).1,3-4 Moreover, stone loss and incidental injuries of the gallbladder are common complications (up to 50%) of laparoscopic cholecystectomy.5-7 A conversion to open surgery is necessary in 2% to 8% of cases.1,4 These complications usually occur when the operating field is obscured by bleeding secondary to dissection. Furthermore, adhesions from prior surgery may make the dissection difficult and contribute to increased intraoperative complications, such as hemorrhage and conversion to an open procedure. Therefore, a bloodless operative field and versatile dissection techniques are paramount for a successful laparoscopic procedure.

To improve the dissection and reduce the dissection-related complications, we utilized a new technology using a high-pressure water stream, which we will refer to by the term “Hydro-Jet” in the following text.

In the industrial arena, the use of high-pressure water flow, 1000 to 2000 atmosphere (atm), has made it possible to precisely cut different materials such as metals,
ceramic, wood, and glass. In the medical field, this technology has also been successfully applied to excision of liver parenchyma, corneal surgery, neurosurgery, and open cholecystectomy. The application of parameters, such as water pressure, probe characteristics (diameter and configuration), and specific water-jet temperature, has made selective dissection and cutting of tissues of various consistencies and elasticities feasible. In the field of laparoscopic surgery, however, except for liver resection, and renal surgery no experience with this new technology is currently available.

We developed a Hydro-Jet probe and a technique of Hydro-Jet dissection for application in laparoscopic cholecystectomies. The goal of this study was to investigate the use of this novel technique and dissector in a porcine model and to compare the results to the standard dissection technique.

**MATERIALS AND METHODS**

**Hydro-Jet Generator and Dissection Probe**

A Muritz 1000 (Euromed Medizintechnik, Schwerin, Germany) Hydro-Jet generator was used (Figure 1). Technical data are summarized in Table 1. This is a newer model, which was originally used for liver surgery. The water pressure can be adjusted in 1 and 5 atmosphere (atm) increments with a maximum of 150 atm using a foot pedal to create a high-pressure water stream. Normal saline (0.9%) was the medium utilized at a temperature of 20°C to 22°C. Actual pressure is continuously monitored during the operation. An adjustable water pressure gauge allowed manual control. A maximum pressure of 30 atm was used. We arrived at this pressure based on our initial experience in renal surgery. Hand pieces for different sized probes (diameter of 80 to 300 µm) with or without integrated suction devices are available.

A modification of the original dissection probe (Euromed, Schwerin, Germany) was developed with an angled tip to extend its use as a water-jet applicator as well as for blunt dissection (Figure 2). The degree of angulation of the tip of the probe is approximately 40°. A 120 µm probe was used. A separate bipolar thermoapplicator and probe for coagulation was applied as needed during the procedures.

| Hydro-Jet/Muritz 1000 | Pressure range | 0-150 atmosphere |
|-----------------------|----------------|------------------|
| Probe diameter        | 120 µm inner radius |
| Pressure mode         | Electrohydraulic |
| Pressure control      | Foot pedal |
| Water velocity        | 32.9 mL/min (120 µm probe, 30 atm) |
| Size                  | 600 (W) x 1470 (H) x 810 (D) mm |
| Weight                | 95kg |
Animals

Thirty pigs with a weight of 16 to 27 (mean 23.6) kg were randomized to undergo laparoscopic cholecystectomy using the Hydro-Jet technique or a conventional laparoscopic cholecystectomy. The laws of the state of Schleswig-Holstein, Germany governing the use and treatment of animals were followed.

Anesthesia

An intramuscular injection of Ketamin (20 mg/kg), Dormicum (2.5 mg), and Atropine (0.5 mg) were initially used. All procedures were performed using a tracheostomy with the pigs under general anesthesia. The animals were sacrificed at the end of the procedures according to laws of the state of Schleswig-Holstein, Germany governing the use and treatment of animals.

Surgical Technique

Using a Veress needle, a pneumoperitoneum (intraabdominal pressure of 15 mm Hg) was created. A subumbilical port was used for camera application. Three further ports: subxiphoid (10 mm), right, and left upper abdomen (5 mm) were then placed under direct vision. The gallbladder was then grasped with a grasping forceps and brought into a ventral position for further dissection. The surgical steps for the operation were identical for this part of the operation. Thereafter, either a conventional dissection or a Hydro-Jet assisted dissection technique was used. A bipolar cautery was used for both techniques.

Conventional Dissection

Conventional laparoscopic cholecystectomy was performed as previously described in humans. Briefly, blunt and sharp dissection were used to identify the cystic duct and cystic artery, which were then individually clipped. Smaller bleeding vessels were coagulated using a bipolar cautery. Further dissection of the gallbladder off of the liver bed was performed as in humans.

Hydro-Jet Technique for Dissection

Initially, water was applied in the subserosal layer at the level of the gallbladder infundibulum and cystic duct junction using the Hydro-Jet probe from a distance of a few centimeters with a maximal pressure of 30 atmosphere. This was performed in a retrograde (toward fundus) and antegrade (along the cystic duct) fashion resulting in an expansion of subserosal space and creation of further surgical planes (Figure 3). Further application of water was performed after insertion of the probe into the subserosal space. The serosa was then further dissected along the cystic duct as well as at the lateral and medial edge of the gallbladder with the probe. Blunt dissection of the cystic duct and cystic artery was done using the bent tip of the probe (Figure 4). These structures were then clipped and transected. Finally, the gallbladder was dissected in a retrograde fashion using application of the Hydro-Jet as well as mechanical dissection. The gallbladder was removed and the bleeding points of the liver bed were controlled using bipolar cautery.

Animals were sacrificed using intravenous injection of T-61 at the end of the procedure. The gallbladder was preserved in 4% formalin for histological examination.

Technical Features and Advantages of the Hydro-Jet

Figure 4 demonstrates the principal of Hydro-Jet dissection. As shown here, Hydro-Jet dissection had tissue selectivity. Application of water around and beneath the serosal layer resulted in expansion of the subserosal space and the creation of surgical planes (Figure 3 and 5). During dissection of the cystic duct and artery, the thin stream of high-pressure water allowed selective separation of surrounding connective tissue components from the vessels and bile duct. Water displaced fibrous and collagenous tissue leaving these structures intact. After removal of the gallbladder, the liver bed was almost...
RESULTS

Comparison of Operative Time and Surgical Complications

Overall, laparoscopic cholecystectomy was successful in all animals, and no conversion to open surgery was required. No vascular injury secondary to dissection or significant intraoperative hemorrhage was noted. Minor bleeding was of a diffuse nature secondary to blunt dissection. The estimated blood loss was minimal (< 50 mL) in both groups. The mean dissection time was 28 (range: 15 to 34) and 36 (range: 25 to 45) minutes for the Hydro-Jet assisted and conventional techniques, respectively ($P = \text{NS}$). Gallbladder perforation occurred in 1 (6.5%) and 3 (20%) pigs in the Hydro-Jet and conventional groups, respectively. Minor liver laceration occurred in 1 (6.5%) and 2 (13%) pigs with the Hydro-Jet and conventional techniques, respectively. No other organ injuries occurred. The mean normal saline used during Hydro-Jet dissection was 195 mL (range: 150 to 250 mL). Overall, although no statistically significant differences were found, the dissection time was shorter and the complication rate was lower with the Hydro-Jet.

DISCUSSION

Dissection-related complications during laparoscopic cholecystectomy may result in hemorrhage, injury to adjacent organs, including the bile duct, with consequent conversion to laparotomy. In a recent review, a conversion rate of 5.3% was reported, and the degree of the surgeon’s experience was a prognostic factor. Today, an increasing number of young surgeons are performing this operation. Although the learning curve improves with time, in the beginning, the complication rate may be higher. Dissection complications mainly occur when the operative field is obscured by hemorrhage, and adhesions secondary to previous operations exist or cholecystitis is present. Therefore, methods to improve the dissection technique may end with better surgical results.

The principle of hydrodissection is the use of a stream of water (pressure 200 to 600 mm Hg) to expand and delineate surgical planes. Nezhat et al described a technique for hydrodissection using a suction-irrigation probe (5 mm diameter) by injecting normal saline into the subperitoneal space to enter the Retzius space. Ostrzenski applied this technique to develop tissue planes during laparoscopic hysterectomy. Hydrodissec-

free of bleeding, and a subsequent hemostasis could be omitted. Using the combined Hydro-Jet dissection and the angled tip dissector (Figure 5), the gallbladder was dissected practically with blunt dissection. Furthermore, continuous water flow allowed a clear view for the operator.
tion was also used for laparoscopic cholecystectomy resulting in fewer complications and faster dissection.\textsuperscript{22}

Although similar in principle, the Hydro-Jet technology utilizes an extremely thin high-pressure stream of water (30 atm or 22 800 mm Hg in our study) that can be used for both blunt dissection and cutting. The application of water between tissue layers creates surgical planes. Moreover, the high-pressure stream of water can be used as a sharp knife to cut parenchymal organs depending on the tissue density and the pressure utilized. Papachristou et al\textsuperscript{9} first used this technology for liver resections in dogs. Vessels and bile ducts were preserved. Recently, Piek et al\textsuperscript{11} described their clinical experience for dissection of brain parenchyma using the Hydro-Jet. Using a maximum pressure of 7 atm, small vessels could be preserved.

The presence of water-laden tissue after Hydro-Jet application has not been a problem in our experience but rather the edema produced facilitated blunt dissection. Back-spray of water can obscure vision and may occur if the camera is held too close to the tissue during water application. This was not a problem and does not occur with the usual distance between the lens and the tissue during laparoscopic cholecystectomy.

The dissecting effect depends on the tissue density, pressure used, and duration of application. Using the 30-atm pressure, the Hydro-Jet has tissue selectivity. Vessels contain more dense collagenous tissue and therefore withstand Hydro-Jet application without damage at this pressure. In our experience, vessels greater than 1 mm in diameter were preserved at 30 atm.

Although the Hydro-Jet dissection proved to be superior to conventional dissection during handling of normal tissue, we did not use this technique for dissection of adhesions in this experimental model. However, hydrodissection has been shown to improve safety and decrease the time spent for adhesiolysis in open abdominal surgery.\textsuperscript{23}

In this porcine model, the use of the Hydro-Jet assisted technique for laparoscopic cholecystectomy allowed precise anatomical dissection. The combination of blunt dissection (with the probe) and the sharp dissection of the soft tissue using the ultra-thin high-pressure water stream resulted in creation of dissection planes and isolation of vascular structures. The tissue selectivity of the Hydro-Jet reduced the risk of vascular and bile duct injuries. This is reflected in the overall lower rate of complications using this technique compared with the standard dissection technique. After removal of the gallbladder, the liver bed is almost free of bleeding and a subsequent hemostasis can be omitted. Therefore, this technique makes the operation easier and less challenging for the less experienced surgeon. Moreover, since both sharp and blunt dissection and irrigation with the new probe is possible, the time spent for changing of instruments is saved. In this experiment, the mean dissection time, although not statistically significant, was reduced from 36 minutes to 28 minutes. A clear operative field secondary to continu-

\begin{figure}[h]
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\caption{Subserosal space prior to the application of the Hydro-Jet. The probe is brought in close proximity to outer connective tissue and the Hydro-Jet is applied. \textbf{Figure 5B}. Expansion of subserosal tissues and preservation of vessels. Water penetrates the soft tissue planes while large vessels are preserved with 30-atm pressure. \textbf{Figure 5C}. Blunt dissection with the bent tip of the probe after water application facilitates isolation of the vascular structures and cystic duct.}
\end{figure}
uous water flow is another advantage of Hydro-Jet dissection. Using this technique, the dissection was performed in a relative bloodless field.

**CONCLUSIONS**

We describe the initial experience with Hydro-Jet dissection for laparoscopic cholecystectomy as an excellent alternative to conventional dissection techniques. Tissue selectivity results in improved anatomical dissection and may decrease complications. Further studies in humans are necessary and are currently underway to investigate this technique.

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