Waterjet Dissection for Partial Nephrectomy Without Hilar Clamping in a Porcine Model

Shengqiang Yu¹, Zhenli Gao¹, Chunhua Lin¹, Xizhi Sun², Changping Men¹, Luxin Yu¹, Diandong Yang¹

¹Department of Urology, Yantai Yuhuangding Hospital, Medical College of Qingdao University, Shandong, China

²Department of Anesthesiology, Yantai Yuhuangding Hospital, Medical College of Qingdao University, Shandong, China

Hilar clamping is typically used in partial nephrectomy to control hemorrhage, which may damage the renal tissue under warm ischemia conditions. The purpose of this study was to evaluate waterjet technology in partial nephrectomy without renal hilar vascular control in a porcine model. Bilateral partial nephrectomy using waterjet was performed in 8 pigs (16 kidneys: 8 for wedge resections, 8 for pole resections). The operations were performed successfully in all animals. The mean dissection time was 30.6 ± 2.9 minutes for pole resections and 36.5 ± 3.5 minutes for wedge resections. The mean blood loss was 51.6 ± 11.7 mL for pole resections and 38.7 ± 9.2 mL for wedge resections. The novel waterjet technique provided precise and effective hydrodissection of the kidney, avoiding damage to the vascular structures or collecting system.

Key words: Partial nephrectomy – Waterjet dissection – Animal experiment

Kidney cancer is one of the most common cancers in the urinary system. More and more asymptomatic small renal tumors are diagnosed because of the wide use of imaging technologies.¹ For decades, radical nephrectomy was considered the gold standard treatment for localized renal cancer. In recent years, nephron-sparing procedures (partial nephrectomy) have been demonstrated to

have similar outcomes to traditional radical nephrectomy for small renal tumors.² However, partial nephrectomy is a challenging operation with a high risk of parenchymal bleeding and damage to the collecting system. Renal hilar vessel clamping is still the first choice to minimize the parenchymal bleeding. Partial nephrectomy is then completed expeditiously under warm ischemia with limited time

Corresponding author: Diandong Yang, MD, Department of Urology, Yantai Yuhuangding Hospital, Medical College of Qingdao University, 20 Yuhuangding Donglu, Yantai, Shandong Province, 264000, China.
Tel.: 86 535 6695579; Fax: 86 535 6695579; E-mail: yangdiandong2013@163.com

constraints.³ However, temporary warm ischemia may lead to renal function deterioration, especially for solitary kidneys. It is imperative to improve the surgical technique of partial nephrectomy without relying on renal hilar clamping.

Waterjet dissection has been used for selective dissection of the parenchyma of liver,⁴⁻⁶ pancreatic necrosectomy,⁷ and endoscopic submucosal dissection for gastrointestinal tumors.⁸⁻¹⁰ In this study, we investigated whether waterjet resection is applicable or feasible for partial nephrectomy without temporary ischemia in a porcine model.

Materials and Methods

The waterjet dissector

Waterjet surgery, a new form of dissection that has been successfully used for several years, separates the different tissue types with their varying elasticity and firmness with the help of precisely adjusted water pressure.⁵⁻⁷ The kinetic energy of the waterjet carefully separates the layers of tissue.⁵⁻⁷ The ERBEJET 2 (ERBE Elektromedizin GmbH, Tübingen, Germany) is a waterjet surgical device for the preparation and separation of tissue, suitable for preserving layering. The selective separation property of water supports the surgeon in the dissection of parenchymal tissue (*e.g.*, liver, spleen, kidney, brain) while sparing blood vessels and nerves. By using ERBEJET2, blood vessels and nerves are preserved by using predefined water pressures, while the surrounding tissue is selectively dissected. Furthermore, the ERBEJET2 is compatible with the advanced electrosurgical controller ERBE VIO (ERBE Elektromedizin).

Animal experiments

Eight pigs, weighing approximately 40 kg each, were placed under general anesthesia by using intravenous pentobarbital (20 mg/kg). Bilateral partial nephrectomy using waterjet was performed without renal hilar clamping in the 8 pigs (16 kidneys: 8 for pole resections, 8 for wedge resections). Kidneys were exposed through an abdominal flank incision. The kidney pole resections and wedge resections were achieved in the lower mid-third of the kidneys. The renal arteries were not clamped during the operation. Renal parenchymal hydrodissection was conducted using the ERBEJET 2 at the working pressure of approximately 16 to 22 bar (1.6–2.2 mPa). The denuded parenchymal blood vessels were precisely coagulated and transected

with the ERBE VIO 300D. For pole resections, the pelvicaliceal system was isolated without being opened, held by a clamp, cut with a scalpel, and then closed with continuous suture. At the end of the surgical procedure, all animals were killed using 8-g intravenous potassium chloride under anesthesia. The protocols for the animal experiments were approved by the Ethical Committee of Yantai Yuhuangding Hospital.

Results

In all 8 pigs (16 kidneys), the partial nephrectomy operations were performed successfully without renal hilar clamping. Eight kidneys had pole resections, and another 8 kidneys had wedge resections. By using the ERBE JET2, the renal parenchyma was washed away (Fig. 1A), and the intrarenal parenchymal vessels were selectively coagulated and transected (Fig. 1B). The slight parenchymal bleeding could be stopped effectively by electrocoagulation, and clamping the hilar vessels was not necessary. After dissection, the collecting system remained intact (Fig. 1C). The mean dissection time was 30.6 ± 2.9 minutes for pole resections and 36.5 ± 3.5 minutes for wedge resections. The mean blood loss was 51.6 ± 11.7 mL for pole resections and 38.7 ± 9.2 mL for wedge resections. The specimen weight was 51.7 ± 11.7 g for pole resections and 33.1 ± 6.4 g for wedge resections (Table 1).

Discussion

Waterjet technology can be used to generate a thin stream of water with high velocity and pressure and has been used as a cutting tool in industry for different materials such as metal and glass. The water stream is ejected from a nozzle that is connected to a high-pressure water pump and can cut through different materials at different water pressures.

In recent years, waterjet technology has been introduced to the surgical field as a tool for dissection and resection of organs.⁴ Waterjet technology had been used for liver operation in dogs and humans with the advantage of selective cutting of liver parenchyma while preserving the bile ducts and vessels.^{4,5} This technology has also been reported to improve the dissection efficiency and reduce the dissection-related complications in urologic surgeries.¹¹

Fig. 1 (A) Renal parenchymal hydrodissection was conducted using the ERBEJET 2 at the working pressure of approximately 16 to 22 bar (1.6–2.2 mPa). The renal parenchyma was washed away, but the blood vessels and collecting system were preserved. (B) The intrarenal parenchymal vessels were selectively coagulated and transected with the ERBE VIO 300D. The slight parenchymal bleeding could also be stopped effectively by electrocoagulation, and clamping the hilar vessels was not necessary. (C) After dissection, the collecting system remained intact.

In 1999, Shekarriz B *et al*¹² first used the hydrojet technique during laparoscopic nephrectomy in a porcine model. Fourteen pigs underwent unilateral laparoscopic nephrectomy using the hydrojet and a conventional laparoscopic nephrectomy contralaterally. Laparoscopic nephrectomy was successful in all animals without conversion to open surgery. Hydrojet dissection allowed improved surgical dissection and shorter dissection time.¹² Then, the hydrojet technique was used for laparoscopic partial ne-

Table 1 Parameters of the experimental groups

	Dissection time, min	Blood loss, mL	Specimen weight, g
Pole resection	30.6 ± 2.9	51.6 ± 11.7	51.7 ± 11.7
Wedge resection	36.5 ± 3.5	38.7 ± 9.2	33.1 ± 6.4

Data are expressed as mean ± SD.

phrectomy in a porcine model. The renal parenchyma was dissected virtually bloodlessly, and the blood vessels and the collecting system were preserved. The vessels were then coagulated under direct vision.¹³ The hydrojet-assisted laparoscopic nephrectomy was also performed successfully in a calf model without hilar vessel control, thus completely avoiding warm ischemia.¹⁴ In 2000, Basting *et al*¹⁵ used hydrojet in open renal sparing surgery without hilar control in 24 patients. They found the hydrojet could achieve precise hemostasis with little damage to the surrounding tissues. The dissection time was 14 to 40 minutes with minimal intraoperative blood loss. No significant postoperative complications occurred.¹⁵

Based on hydrojet technology, ERBE JET 2 is a newly developed waterjet dissector with a new pump and nozzle applicator system.¹⁶ The ERBE JET 2 has an easy-to-operate user interface. The parameters can be adjusted according to the individual indications and saved in 9 different program settings. The impact of the waterjet is available as finely adjustable steps that create reproducible dissection results, and the setting can even be altered during activation. The pump unit of the ERBEJET 2 allows continuous application of the waterjet. The separating medium is a sterile saline solution. It is connected to the system in the form of standard infusion containers.

The interface of the ERBE JET 2 is also used to enter the settings for the suction module ESM 2, adjusting the type of activation and the degree of suction; and activation occurs either simultaneous to the application of the waterjet or is switched on as required using the foot switch. The suction pump can be programmed to continue running for a certain time after the waterjet is no longer activated. This ensures good visibility at the operative site even after the waterjet has been deactivated.

In the present study, we successfully performed open partial nephrectomy operations without renal hilar clamping in 8 pigs (16 kidneys) with the ERBE JET 2. At the pressure of approximately 16 to 22 bar (1.6–2.2 mPa), the renal parenchyma was washed

away, but the blood vessels and collecting system were preserved. The intrarenal parenchymal vessels were then selectively coagulated and transected. The slight parenchymal bleeding could be stopped effectively by electrocoagulation, and clamping the hilar vessels was not necessary. Compared with the traditional partial nephrectomy operations, the waterjet (ERBE JET 2) surgery has several advantages:

1. In the whole process of the operation, the renal hilar is not blocked, which could avoid the damage of warm ischemia completely and extend the time constraints.
2. During the dissection, the blood vessels are preserved and then selectively coagulated and transected, which allows precise hemostasis and reduces the blood loss obviously.
3. The continuous water flow and ESM 2 Suction module allows anatomic planes to be created in a relatively bloodless field and provides a clear view for the operator.
4. The pelvicaliceal system is not disturbed during the dissection, thus the urinary extravasation after surgery is properly prevented.
5. The water stream is a “cold” water knife, which does not produce thermal damage to the tissue, unlike the electrotome or laser.

Overall, in the present study, we evaluated the waterjet (ERBE JET 2) for partial nephrectomy without hilar clamping in a porcine model and found some advantages of the new dissector. These advantages might improve the dissection and reduce the complication rate when applied to humans. Further experience in humans is necessary to evaluate the efficacy and advantages of this technique for partial nephrectomy.

Acknowledgments

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