Cutting with a high pressure stream of water has been used in industry for years. A niche has since been found for this technology in medical procedures such as wound débridement and thrombectomy; in arthroscopic and spinal surgery; in plastic surgery such as liposuction and tattoo removal; in endoscopic sinus surgery; and in ophthalmology. Papachristou and Barters first described the use of water jet surgical dissection in 1982, when they used a jet of saline from an agricultural sprayer to perform liver resections in four patients. They concluded that the use of the water jet reduced blood loss during surgery. This summary focuses on the use of water jet systems in the resection of organs such as the liver, gallbladder, kidneys and brain.

### Manufacturer:
- Helix Hydro-Jet® (Andreas Pein Medizintechnik GmbH, Germany; ERBE Elektromedizin GmbH / ERBE USA Incorporated hold global distribution rights for the Helix Hydro-Jet)
- VersaJet Hydrosurgery System (HydroCision Inc., US)
- Handy-jet™ (Saphir Medical, France)
- Hepatotom (Meditech, Switzerland)
- Liquitom™ (Medaxis, Ammann-Technik AG, Switzerland)
- Parenchimotom 01 (TOSA, Bulgaria).

### Purpose:
Controlling bleeding during and after surgery involving solid organs is a concern. Water jet dissecting systems allows for more selective cutting through organ tissue, with less surgical trauma and blood loss.

### Current Regulatory Status:
Health Canada licensed the Helix Hydro-Jet system in December 2001. The intended use of the device is for the selective dissection of soft tissues using pressurized saline (Kathleen Savage, Health Canada, Ottawa: personal communication, 2003 July 16). The US Food and Drug Administration 510(k) authorization for the Helix Hydro-Jet defines the intended use for the device as “… cutting and dissection of soft tissue such as the liver, kidney, etc. within the abdomen, including Total Mesorectal Excision (TME), in open as well as laparoscopic surgery.”

The VersaJet Hydrosurgery System (HydroCision, Inc.) was licensed by Health Canada in July 2002 for use in wound and soft tissue débridement, and cleansing of the surgical site (Kathleen Savage, Health Canada, Ottawa: personal communication, 2003 July 16). According to the manufacturer, the Canadian and US Food and Drug Administration’s (FDA) authorizations for the VersaJet have recently been amended to include the following indications: “… cutting, resection and removal of tissue, contaminants or fluids from the wound or surgical site. Applications include general, plastic, orthopaedic, trauma and vascular surgery” (James H. Hill, HydroCision Inc., Andover (MA): personal communication, 2003 July 17). Although the expanded licensing authorizations include general surgery, the VersaJet’s primary application to date has been in surgical débridement. Clinical studies of the system for organ resection are planned, but are not yet underway (James H. Hill, HydroCision Inc., Andover (MA): personal communication, 2003 October 6).
Several other commercial water jet dissecting systems intended for use in surgical resection are available in Europe but are not licensed in Canada.

**Description:** Water jet systems use a fine stream of high pressure saline solution to cut through tissue. Adjustments to the level of pressure allow the surgeon to selectively cut through organ parenchyma, but not other structures, such as major blood vessels, ducts or lymph vessels. These devices often include an aspiration tube to remove tissue debris and fluid as the cutting occurs. As a UK review of dissection techniques in laparoscopic surgery explains: “The advantages of water-jet cutting include simplicity of the device, low maintenance cost, clean cutting and reproducibility of the depth of the cut depending on the energy of the coherent water-jet.” The mechanics used to create the water jet differ between the systems.

**Cost:** The Helix Hydro-Jet system costs C$179,900. The disposable applicators used for different surgical procedures range in cost depending on their configuration and size. For example, a box of 10 applicators in the most commonly used size costs C$4,779.28 (Bill Roberts, AMT Electrosurgery, Kitchener (ON): personal communication, 2003 October 3).


**Evidence:** Most of the studies of water jet dissection have been done in Europe and Japan, so many reports have been published in languages other than English. This summary reviews only papers published in English or those with English abstracts. In general, the studies are small, uncontrolled series that have looked at the use of this technology in liver or hepatobiliary surgery and in open and laparoscopic surgery. Researchers have also investigated the use of water jet systems in brain surgery. The larger published studies for indications involving the brain and the organs of the abdomen are summarized here.

**Gallbladder**

A recent randomized controlled trial of 80 patients compared the use of water jet dissection (Helix Hydro-Jet) with conventional dissection in laparoscopic cholecystectomy. Complication rates were reduced when the water jet was used. In particular, gallbladder perforation occurred in 15% (n=6/40) of the water jet procedures, compared with 30% (n=12/40) of the conventional dissections. Liver laceration requiring the use of hemostatic agents to control bleeding occurred in 10% of the conventional procedures (n=4), but in none of the water jet procedures. Use of the water jet reduced dissection time, but not significantly.
The authors explained that many of the complications associated with laparoscopic cholecystectomy occurred when the operative field was “obscured by hemorrhage and adhesions from previous operations or the presence of acute inflammation…” The tissue selectivity of the water jet reduced bleeding and the continuous water flow helped to provide a clear operative field for the surgeon, although the field may be obscured by the spray of the saline solution. The learning curve for using the water jet was short. Though the study did not include a formal cost analysis, the authors believed that this technology would increase surgical costs because of the costs of the system and of the disposables. Whether overall costs might be reduced through decreased complication rates is yet to be determined. Expanded use of the technology for surgical procedures may decrease the costs involved.

**Kidneys**

Basting *et al.* reported on their use of the Helix Hydro-Jet in 24 patients who underwent open surgery for conditions such as renal-cell cancer (partial nephrectomy) and kidney stones (nephrolithotomy). Histologic analyses revealed that the water jet produced a sharp dissection line, with vacuolization of 100 µm to 300 µm; and reduced trauma to adjacent tissue in comparison with thermal methods of dissection (electric cautery or laser). The water jet dissections lasted between 14 and 35 minutes, with an average blood loss of 60 mL. The length of hospital stay was similar to that for other kidney surgeries – an average of 10.1 days. No major complications were reported during the follow-up period of two to 17 months.

**Liver**

In the early 1990s, Baer *et al.* published several studies on the use of a high pressure water jet system (the Hepatom or Hepatotom) in liver surgery. The most recent paper from this group compared 67 resections for liver tumours. Manual separation of the tissue (finger fracture technique) was used for 51 patients and water jet dissection was used for 16 patients. Four complications were reported in the water jet group: one patient had a biliary fistula and three patients required treatment for postoperative intra-abdominal fluid collection and infection. Two of these three patients had preoperative conditions that may have predisposed them to these complications. Though this study found no significant differences in operating times, the authors reported a significant decrease in the need for blood transfusion in the water jet group (a mean of 2.0 units) compared with the finger fracture group (a mean of 5.2 units).

Rau *et al.* compared laparoscopic liver resection using water jet systems (Jet-Cutter and Helix Hydro-Jet) in 17 patients, with a matched pair control group of patients who underwent conventional liver resection during the same period. The operating time was significantly shorter with the conventional surgery. Though blood loss was less in the laparoscopic group, it was not significantly reduced. The main advantage
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seemed to be the reduced length of hospital stay - 7.8±8.2 days in the laparoscopic group and 11.6±12.8 days in the conventional surgery group. However, this is likely due to the use of the laparoscopic procedure, rather than to the use of water jet dissection. The authors concluded that the water jet permitted more selective dissection of the liver parenchyma.

In an earlier paper, Rau et al. compared liver resections in 116 patients using three techniques: blunt dissection (n=61), the cavitational ultrasonic surgical aspirator (CUSA®) (n=28) and the Jet-Cutter (n=27). The authors correlated several outcomes per area of liver surface resected. They found that the amount of blood loss per area of resected liver surface was lower with water jet dissection than with either of the other two methods. The number of blood units transfused (per cm² of liver resected) was also reduced with water jet dissection (0.026±0.014 mL) compared with CUSA (0.079±0.145 mL) and blunt dissection (0.066±0.039 mL). Liver hilus clamping to reduce blood loss was performed in 60% of the patients in the blunt dissection group, 82% of the CUSA patients and 65% of those in the water jet group. The duration of hilus clamping and resection relative to the area of liver resected was significantly shorter in the water jet group. Laboratory measures of liver tissue trauma did not show a significant difference among the three methods.

In another study by Rau et al., 61 patients undergoing liver resection were randomized to receive resection with either CUSA (n=30) or the Jet-Cutter (n=31). The time for resections using the water jet was significantly shorter (28±11 minutes) compared with the CUSA (46±19 minutes). The duration of liver ischemia was also reduced: water jet (29±12 minutes) versus CUSA (39±16 minutes). The need for blood transfusion was significantly less with the water jet dissection (a mean of 1.5 units) versus the CUSA (a mean of 2.5 units).

Few adverse events have been associated with the use of water jet dissection systems. An early case report of possible venous air embolism in a patient undergoing liver resection with a water jet (Hepatatom) may have been due to the positioning of the patient during surgery, rather than to the use of the water jet.

Mesorectal excision

An uncontrolled study involving 30 patients with rectal cancer found that water jet dissection (Helix Hydro-Jet) allowed removal of the mesorectum from the pelvis while preserving hypogastric nerves and resulting in less postoperative bladder dysfunction. The authors suggested that if the saline solution used in the water jet is replaced with a cytotoxic solution, this might provide an additional prophylactic measure against local recurrence of cancer.

Neurological procedures

Piek et al. reported on the use of water jet dissection (Helix Hydro-Jet and an earlier version of this device, the Müritz 1000) in neurological procedures. Their study
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included 35 patients with brain tumours (n=27), epilepsy (n=8) and internal carotid artery stenosis (n=1). The water jet’s pressure was adjusted to suit the different levels of cutting needed for different conditions. No complications due to the use of the water jet were reported. The investigators found that the device was more useful in some procedures than in others. For example, in patients with gliomas, the water jet was particularly useful in the dissection of well vascularized tumours – dissecting and aspirating the tumour while preserving the blood vessels. These were then coagulated, causing minimal bleeding. In patients with firm, well defined metastatic tumours, the water jet facilitated dissection of the tumours and identification of the tumour-supplying blood vessels for subsequent coagulation with minimal blood loss. With lower pressure levels, the water jet enabled resection of the brain tissue in patients with epilepsy, while the blood vessels were preserved. None of the epilepsy patients experienced postoperative brain edema, possibly because the water jet caused less surgical trauma. For conditions such as certain types of meningiomas, the water jet was not found to be useful, though the authors cautioned that the number of patients was small and that the results should be considered preliminary. In the patient with internal carotid artery stenosis, the water jet offered no advantage over microsurgical resection. Piek et al. concluded that the water jet may facilitate resection in certain neurological procedures with less intraoperative blood loss, a reduced risk of postoperative edema and no increase in duration of the surgery.

In a recent paper, the same authors reported their experience with water jet resection of brain metastases in 10 patients. They concluded that “… the separation of firm, clearly demarcated brain metastases from the brain parenchyma is easily and accurately achieved with conventional methods. Thus at present, we do not see an indication for the application of the [water jet] instrument under these conditions. In contrast, the water jet device appears to be particularly helpful in the separation of soft, poorly demarcated brain metastases from the surrounding brain parenchyma. This separation remains rather challenging with conventional methods, often a plane between tumour and adjacent parenchyma is difficult to establish, and tumour remnants causing early recurrences are left in situ. Based on the present results in six such tumours, the water jet enables precise and accurate tumour separation from the brain leaving the adjacent brain intact.”

The authors concluded that the water jet will be useful in certain neurological procedures, but that further studies were needed to determine where it offered advantages over conventional methods. The potential for increased risk of infection or tumour seeding due to the use of the water jet also needed further investigation, though the authors found no evidence of these.

Available Alternative Technologies:

Various tools and techniques are used in surgical dissection of organ tissue. These include instruments such as scalpels and scissors, ultrasonic cutting and coagulating systems, such as the Harmonic Scalpel® or the cavitational ultrasonic surgical aspirator (CUSA®), electrosurgical and laser systems. Blunt dissection, where the tissue is
torn apart, rather than cut, may also be used. For example, in liver surgery, the “finger fracture technique” is used to separate the parenchyma (tissue) manually. Some devices coagulate and cut. Unlike some cutting devices, water jet systems cause only a slight rise in temperature, thereby minimizing thermal damage to tissue. This may be important when conducting surgery on brain or neural structures.7

Commentary: There is little evidence on the use of some commercially available water jet systems in surgical resection and there are no published studies that compare the performance of different systems.

Many of the earliest published studies used first generation or prototype devices.20-24 It is difficult to determine from more recent studies whether initial problems with these devices, including spray and the formation of air bubbles obscuring vision in the surgical field; concerns about possible contamination of the operating field; and concerns about tumour seeding, have been resolved.

An expansion of uses for water jet dissecting systems is likely. This may allow more cost-effective use of these devices.6 A 2002 press release from ERBE USA notes that further studies of the Helix Hydro-Jet in living donor liver transplantation, nerve-sparing retropubic radical prostatectomy and cancer-related procedures are underway in the United States.25

The evidence indicates that the use of water jet dissection can reduce blood loss and transfusion requirements. In some procedures, resection time and the period of normothermic ischemia can be reduced. The learning curve for this technology seems to be relatively short. More studies are needed to determine whether water jet resection in cancer patients poses a risk of tumour reseeding. The published evidence, mainly from older reports of small, uncontrolled studies, supports the use of the water jet in reducing blood loss and surgical trauma in liver surgery. Fewer studies have been published on the use of water jets in kidney surgery, though it seems to offer similar benefits.6 The recent randomized trial by Shekarriz et al. indicates that water jet dissection may offer advantages over conventional laparoscopic cholecystectomy, as it may significantly reduce associated complications and blood loss.6

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This series highlights medical technologies that are not yet in widespread use in Canada and that may have a significant impact on health care. The contents are based on information from early experience with the technology; however, further evidence may become available in the future. These summaries are not intended to replace professional medical advice. They are compiled as an information service for those involved in planning and providing health care in Canada.

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