

Prospective analysis of hepatic resection by three techniques in 121 patients

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Objective The aim of this study was to evaluate three techniques for liver resection: blunt dissection, ultrasonic aspirator (CUSA) and Jet-cutter.

Methods In a prospective study 121 patients underwent liver resection. The operation data were analysed regarding speed of resection, blood loss, transfusion rate, liver hilus clamping time and tissue damage on the basis of area of transected liver surface.

Results Liver resection with the Jet-cutter was significantly faster with a resection time of 0,35 min/cm² in

comparison to blunt dissection (0,57 min/cm²) and CUSA (0,77 min/cm²) ($p < 0,05$), and associated with lesser blood loss of 17,7 ml/cm² ($p < 0,01$) than the other techniques (Blunt dissection 32,5 ml/cm², CUSA 34,4 ml/cm²).

Conclusion The Jet-cutter is a promising new instrument in liver surgery.

Key words Jet-cutting, ultrasonic aspirator, blunt dissection, resection time, liver resection.

Introduction

The importance of anatomical liver resection has increased during last years (1).

To remove the tumor with a sufficient safety margin and preserve as much liver tissue as possible is the aim in the resection of primary liver neoplasms and metastases of distant primaries. Reduction of following aspects is required to improve operative results.

Blood loss

Resection time

Interruption of blood flow in the main vessels (hepatic artery and portal vein) to minimize normothermic ischemia time.

Damage to the afferent and efferent vessels and bile ducts of segments that follow (during resection of central segments).

Because of discrimination between vascular structures and parenchyma thermal processes such as laser and high frequency electrocautery play a minor role in liver surgery. Widely used is the finger fracture technique first described by Lin in 1958 (2,3). By crushing the parenchyma between the fingers in order to isolate larger vessels, the liver is divided (4). Surgical instruments such as small clamors for blunt dissection improved this technique. In last years advanced technical devices have been introduced. The ultrasonic aspirator (CUSA) has gained the most widespread acceptance among these (5,6). The Jet-Cutter was developed recently and allows selective cutting of parenchymatous organs. A liquid is pressurized by a high pressure pump and is conducted by a high pressure hose to a nozzle. Here the pressure is converted into kinetic energy. For jetcutting of

parenchymal tissue pressures of 10-80 bar and nozzles with a diameter of 0.05-0.2 mm have been employed (7-9). The soft liver tissue is washed off the more resistant vessels and bile ducts. The effect is similar to the one obtained with the CUSA. Structures are isolated and can be transected under controlled conditions. The results of experimental studies show equal selectivity but higher cutting speed when compared to the CUSA (10). The study presented here analysed whether or not these experimental results can be confirmed in a clinical setting.

Material and method

A prospective clinical study was carried out between January 1990 and December 1993. The study was designed and planned as a randomised study, but during the course of the study there were time periods when the randomisation was not possible because the Jet-Cutter could not be used. This was due to technical problems occurring postoperatively when the nozzle obstructed irreversibly with clotted blood after use. Because of limited supply of parts for the Jet-Cutter prototype that was not yet commercially available the delay until replacement of the nozzle arrived was up to six weeks, and this waiting period was unacceptable for patients scheduled for resection of malignant tumors. When the Jet-Cutter was ready to use there was no technical failure intraoperatively.

With 3 different methods of blunt dissection, CUSA and Jet-Cutter, a total of 121 patients underwent partial hepatic resections. All techniques were used by 6 experienced surgeons trained at our institution by the same surgical principles. Liver hilus clamping was applied individually depending on

the intraoperative surgical situation to prevent unnecessary liver ischemia.

To compare the techniques the following parameters were evaluated: blood loss, speed of resection, liver hilus clamping time, the need of additional methods for haemorrhage control, and tissue trauma. The comparison of the parameters listed above based on the area of the cutting surface that was measured in all resected specimens.

Several parameters were analysed preoperatively. Besides, a risk profile assessing the general operability of the patient liver enzymes and liver function tests were analysed in detail. Preoperative CT scan of the abdomen and ultrasound allowed an evaluation of the tumor size and involvement of the liver. According to the method described by Okayrcoto (11) the Parenchymal Hepatic Resection Rate (PHRR) was calculated by computer-assisted measurement of the preoperative CT scans of the abdomen in patients scheduled for extended liver resections. (Table 3). The following appliances and materials were used: Ultrasonic Surgical Aspirator 'CUSA System 200' (Cavitron, Stamford CT, USA), 'Jet-Cutter 4' (BMTL, Lübeck, Germany: 60-80 bar, nozzle 0.1 mm, electrolyte solution heated up to 50°C), Argon beam 'Beamer ONE' (Erbe, Tübingen, Germany), Infrared Sapphire Coagulator 'ISK 250' (NK Optik, Munich, Germany), fibrin sealant 'Tissucal DuoS' (Immuno, Heidelberg, Germany), collagen fleece 'Lysostypt' (Braun, Melsungen, Germany). For each patient were entered into the data collection:

Parenchymal Hepatic Resection Rate (%).

Area of cutting surface: measurement of the specimen by pathologist (cm²).

Blood loss: Volume collected in the suction pump, estimated amount absorbed by towels (ml).

Blood transfusions: units as documented by the anesthesiologist (1 unit = 250 ml RBC).

Time measurements: liver hilus clamping time, liver resection time (min).

Weight of the resected liver specimen (g).

Laboratory parameters pre-operatively and on postoperative day 2 and 7: Hemoglobin, SGOT, SGPT, Prothrombin test, Bilirubin.

Mean (m), Standard deviation (Std. dev), Linear Regression, Kruskal-Wallis and Mann-Whitney Tests were used for statistical analysis.

Results

Regarding age or gender, there were no significant differences between the patient groups.

The mean age in the Blunt Dissection group was 55,1 ± 13,7 years, in the CUSA group 61,5 ± 16,7 years and in the Jet-Cutter group 58,8 ± 13,4 years.

The extent of hepatic resection quantified by Parenchymal Hepatic Resection Rate and weight of the resected liver specimen did not differ significantly between the three groups (Table 1).

Metastases of colorectal primaries were the indication for operation in the majority of resections in all groups, a total of 61,7% for the entire study population. Other liver tumors were evenly distributed in all groups and less often were the indication for resection (Table 2). The extent of hepatic resections was comparable in all three groups.

The results of blood loss, transfusion requirements, speed of resection and duration of liver hilus clamping were compared for the three techniques on the basis of the area of transected liver surface.

A highly significant linear correlation between blood loss and area of transected liver surface ($p < 0.001$) was detected after pooling the data from all resection techniques. For the Jet-Cutter the blood loss per area of transected liver surface was significantly lower ($p < 0.05$) than for the other two techniques (Table 4).

The number of blood units transfused per area of resection surface was lower for resections with the Jet-Cutter than for the other two techniques (Table 4). For the Jet-Cutter the speed of the resection defined as resection time per area of the resection surface was significantly faster than for the other two techniques. ($p < 0.01$) (Table 4).

Liver hilus clamping was not always necessary in order to reduce blood loss. The overall percentage of patients not receiving liver hilus clamping was 33. It was carried out in 60 % of blunt dissection, 82 % of CUSA and 65 % of Jet-Cutting patients. The duration of warm ischemia due to liver hilus clamping was estimated for all procedures. A significant shorter duration of hilus clamping time relative to the size of the resection surface was achieved with the Jet-Cutter when compared to the other methods ($p < 0.01$) (Table 4).

For additional haemorrhage control on the resection surface high frequency electrocautery was regularly employed. It was also used to mark the line of resection onto the liver surface and coagulate minor subcapsular vessels.

Table 1. Weight of resected liver tissue and parenchymal hepatic resection rate (PHRR)(mean and standard deviation)

Technique	n	weight of specimen (g)	n	PHRR (%)
Blunt dissection	61	374.4±387.7	35	21.5±16.2
CUSA	30	442.8±374.9	15	17.3±20.1
Jet-Cutter	30	368.7±387.1	17	25.0±23.8
Kruskal-Wallis		n. s.		n. s.

Table 2. Indication for liver resection

Technique	Haemangioma	FNH	Adenoma	Echinococcus	HCC	Metastases
Blunt dissection	3	3	5	7	10	33
CUSA	1	2	2	1	5	19
Jet-Cutter	2	0	3	1	5	19

Table 3. Liver resection- Type of operation in 121 patients

Technique	Atyp. Resection	LOBectomy	Segmentectomy	Hemihepatectomy
Blunt dissection	19	6	20	19
CUSA	7	1	20	7
Jet-Cutter	8	1	19	11

Table 4. Mean and Standard Deviation in blood loss, blood transfusions, Hilus clamping time and resection time per area of resected liver surface

Technique	n	blood loss / area [ml/cm ²]	blood transfusions/ area [U/cm ²]
Blunt dissection	61	32.5±27.6	0.07±0.04
CUSA	30	34.4±43.3	0.07±0.07
Jet-Cutter	30	18.4±12.9	0.02±0.01
*p<0.06		*	*

Technique	n	clamp time/ area [min/cm ²]	resection time/ area [min/cm ²]
Blunt dissection	61	0.64±0.48	0.57±0.39
CUSA	30	0.62±0.37	0.77±0.42
Jet-Cutter	30	0.35±0.18	0.35±0.15
**p<0.01		**	**

U = 1 Unit = 250 ml red blood cells

Table 5. Methods for additional haemorrhage control

Thermic devices				
Technique	n	Argon beam	Infrarotkoagulator	total in % of n
Blunt dissection	61	5	22	44
CUSA	30	9	6	50
Jet-Cutter	30	4	1	19
haemostatic agents				
Technique	n	Kollagenlyties	Fibrinolyser	total in % of n
Blunt dissection	61	11	45	92
CUSA	30	4	26	93
Jet-Cutter	30	5	19	89

Table 6. Postoperative complications

Technique	Biliary fistula	Bleeding	Hepatic failure
Blunt dissection	2	1	2
CUSA	1	1	2
Jet-Cutter	1	0	1

When electrocoagulation was not sufficient an Argon beam and Infrared Coagulator were used. They were required in only 19% of the procedures carried out with the Jet-Cutter compared with over 44% in the other two groups (Table 5). The employment of these devices became necessary in almost every other case during resections with the CUSA. Collagen fleece and fibrin sealant were used at the end of surgery in almost all resections with the CUSA and Jet-Cutter to seal the liver surface. After blunt dissection these measures were less often used (Table 5).

There was no operative or hospital mortality in the study group. In 10 patients (10/121 pts=8.3%) postoperative complications occurred. The main complication was bile fistula (n=7) followed by liver failure (n=5) and postoperative haemorrhage (n=2) without differences between the three groups (Table 6).

No significant differences between 3 groups could be detected regarding the transaminases SGOT and SGPT, bilirubin level and coagulability tests.

Discussion

Blood loss is a major problem in hepatic resection, and the substitution of homologous blood is a poor solution. Besides the transmittance of infectious diseases such as hepatitis and HIV it is associated with an increase in postoperative septic complications and possibly a poorer long term prognosis for oncologic reasons (12). A significantly higher 2 year recurrency rate of malignant disease for patients with a blood loss of more than 3.5 liters during hepatic resection for colorectal metastases was reported by Holm (13).

In an attempt to solve the problem of haemorrhage control several techniques have been developed, for example temporary compression of the hepatic artery (14) and portal vein, or selective transhepatic balloon occlusion of the portal vein and hepatic artery (15). The tolerance of the liver to normothermic ischemia (15-90 min.) limits the duration of liver hilus clamping. Additionally that bleeding from hepatic veins cannot be controlled (4,16,17).

Hope for a reduction of blood loss increased with the introduction of the CUSA into liver surgery. Several comparative clinical studies proved a reduction of blood loss during anatomic liver resection with the CUSA in comparison to conventional techniques (15,18-22).

With the data from our own prospective study we were not able to support the positive results

obtained with the CUSA. In our patients treated with the CUSA blood loss was not lower than in patients treated with blunt dissection. It was however significantly higher than in patients resected with the Jet-Cutter ($p < 0.02$). In a report on 30 liver resections with the Jet-Cutter (23) Horie found no differences between the Jet-Cutter and the CUSA with respect to blood loss. From the same group of investigators Une supports these results in a series of 35 patients operated with the Jet-Cutter (9).

Between the Jet-Cutter used by Horie or Une and the one employed in our series are several important differences. They pressurized a full electrolyte solution with a piston pump. The working pressure ranged from 30 to 50 bar and the nozzles employed had a diameter between 0.15 and 0.2 mm. In contrast, we used a pressure of 60-80 bar and nozzles with a diameter of 0.1 mm. In addition, our cutting solution was heated to 40°C which reduced unwanted foaming and possibly had a positive influence on the local blood coagulation. The differences pointed out above may explain the differences in results obtained with our machine when compared to the blunt dissection and especially the CUSA techniques even though both devices are basically similar.

In 85 % of the resections by CUSA liver hilus clamping was carried out but that this was the case in only 65 % of the patients treated with the Jet-Cutter. This is important when evaluating the results obtained with respect to blood loss per area of resection surface with the Jet-Cutter in comparison to the CUSA. Respecting this the results obtained with the Jet-Cutter appear even better.

The reduced use of additional technical devices to aid in haemorrhage control also shows the reduction of blood loss from the resection surface in the Jet Cutter group. The Argon beam was required in 19 % of the resections in addition to electrocautery in the group operated with the Jet-Cutter. In the groups resected by blunt dissection or CUSA the Argon beam and Infrared Coagulator became necessary in 44 % and 50 % of the interventions, respectively. Fibrin sealant and collagen fleece as locally active haemostatic substances were applied to the resection surface in the majority of cases in all groups (Table 5).

There are different risks for the patient implied in the different types of liver resections e.g. atypical resections, segmentectomies and hemihepatectomies. The demands on the surgical team carrying out the procedure vary widely. A resection

of segment 8 can be more difficult and time consuming than a hemihepatectomy. The comparison of results in segmentectomies with those obtained in larger or less extended resections is therefore limited. In all groups the types of resections were evenly distributed (Table 3) and a linear correlation between blood loss and the area of transected liver surface to be highly significant was obtained ($p < 0.001$). We took the area of transected liver surface as a basis of comparison for the parameters blood loss, speed of resection and liver hilus clamping time. For all of these parameters the results obtained with the Jet-Cutter were significantly better than with blunt dissection or the CUSA.

To examine differences in the mortality or morbidity was not the aim of our study. A larger series of patients would have to be operated for such an analysis. In all groups postoperative complication rates were similar, independent of the technique employed. In the clinical course of patients after the operation in respect to bile leakage, hepatic failure and postoperative infection rates were not different (Table 6).

We consider the Jet-Cutter to be a promising new instrument in liver surgery. Our study shows that the use of the Jet-Cutter for liver resection reduces operating time and blood loss per resection area significantly compared with blunt dissection and CUSA.

References

- Couinaud C. *Le Foie*. Études Anatomiques et Chirurgicales. NY: Masson Publishing USA Inc 1957.
- Lin TY, Tzu KY, Mien C, Chen. CS Study on lobectomy of the liver. *J Formosa Med Assoc*; 57: 742-759, 1958.
- Lin TY. Results in 107 hepatic lobectomies with a preliminary report on the use of a clamp to reduce blood loss. *Ann Surg* 177: 413-421, 1973.
- Pachter HL, Spencer FC, Holsbeter FC, Coppa GF. Experience with the finger fracture technique to achieve intrahepatic hemostasis in 75 patients with severe injuries of the liver. *Ann Surg* 197: 771, 1983.
- Hodgson WJ, DeGuercio LR. Preliminary experience in liver surgery using the ultrasonic scalpel. *Surgery* 95: 230-234, 1984.
- Scheele J. Segment-oriented liver resection. Principles-technic-status. *Chirurg* 60: 251-265, 1989.
- Persson BG, Jeppsson B, Tranberg KG, et al. Transection of the liver with a waterjet. *Surg Gynecol Obstet* 168: 267-268, 1989.
- Papschristou DN, Banters R. Resection of the Liver with a water jet. *Br J Surg* 69: 93-94, 1982.
- Ume Y, Uchino J, Horie T, et al. Liver resection using a waterjet. *Cancer Chemother Pharmacol* 23 Suppl: S74-S77, 1989.
- Rau HG, Arnold H, Schildberg FW. Schnäidan mit dem Wasserstrahl (Jet-Cutting) eine Alternative zum Ultraschallaspirator. *Chirurg* 61: 735-738, 1990.
- Okamoto E, Kyo A, Yamamoto N, Tanaka N, Kuwata K. Prediction of safe limits of hepatectomy by combined volumetric and functional measurements in patients with impaired hepatic function. *Surgery* 95: 586-92, 1984.
- Heiss MM, Mempel W, Deleroff Ch, et al. Die Eigenblutperle (EBS) bei Tumorpasienten. *Chirurgische Gastroenterologie* 8: 92-96, 1992.
- Holm A, Bradley E, Aldrete JS. Hepatic resection of metastasis from colorectal carcinoma. Morbidity, mortality, and pattern of recurrence. *Ann Surg* 209: 428-434, 1989.
- Pringle JH. Notes on the arrest of hepatic hemorrhage due to trauma. *Ann Surg* 48: 541, 1908.
- Castaing D, Garden OJ, Bismuth H. Segmental liver resection using ultrasound-guided selective portal venous occlusion. *Ann Surg* 210: 20-23, 1989.
- Delus A, Carrus Y, Noedlinger B, et al. Vascular occlusions for liver resections. Operative management and tolerance to hepatic ischemia: 142 cases. *Ann Surg* 209: 211-218, 1989.
- Huguet C, Gavelli A, Chieco PA, et al. Liver ischemia for hepatic resection: where is the limit? *Surgery* 111: 251-259, 1992.
- Little JM, Hollands MJ. Impact of the CUSA and operative ultrasonis on hepatic resection. *HPB Surg* 3: 271-277, 1991.
- Hardy KJ, Martin J, Fletcher DR, et al. Hepatic resection: value of operative ultrasound and ultrasonic dissection. *Aust N Z J Surg* 59: 621-623, 1989.
- Fasulo F, Giori A, Fassi S, et al. Caotiron Ultrasonic Surgical Aspirator (CUSA) in liver resection. *Irv Surg* 77: 64-66, 1992.
- de Jong KP, Blankenstein JD, Hesselink EJ, et al. Partial hepatectomy for benign or malignant liver diseases: experience in 94 patients. *Ned Tijdschr Geneeskd* 133: 2385-2388, 1989.
- Storck BH, Rutgers EJ, Gortzak E, Zoetmulder FA. The impact of the CUSA ultrasonic dissection device on major liver resections. *Neth J Surg* 43: 99-101, 1991.
- Horie T. Liver resection by waterjet. *Nippon Geka Gakkai Zasshi* 90: 82-92, 1989.

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