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ORIGINAL ARTICLE

The three-surgeon technique for liver tissue dissection: towards real bloodless hepatectomy

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Summary

Purpose: *Bleeding during hepatectomy remains a major cause of mortality despite recent developments in surgical and anaesthetic techniques. To date there is no single surgical device that combines speed, efficient haemostasis and safety for the adjacent vital structures during parenchymal division. This article presents the Three Surgeon Technique (3ST), a novel method of parenchymal dissection for major hepatectomies and compare it with our standard radiofrequency ablation (RFA) - assisted technique.*

Methods: *77 patients who underwent major liver resection were divided into two groups: 38 of them (group A) underwent 41 RFA-assisted liver resections and 39 (group B) underwent 41 hepatectomies with the 3ST. The data for the 3ST were prospectively collected and compared to the already collated RFA patient group.*

Results: *Blood transfusion was necessary in 28 and 13 patients in group A and B respectively (p=0.016), with an average of 1.7 and 0.6 units of red blood cells (p<0.001). The Pringle maneuver was not required with the 3ST. The mean time of parenchymal dissection was 90.49 and 77.52 min in group A and B, respectively (p=0.007).*

Conclusion: *The 3ST is a novel, reliable and safe alternative to the stand alone RFA-assisted technique. It is a faster procedure, and requires less blood units transfusion.*

Key words: bloodless surgery, hepatectomy, parenchymal transaction, radiofrequency ablation

Introduction

Hepatic resection is widely accepted as the only potentially curative treatment for patients with a wide variety of liver conditions such as benign hepatic lesions, primary and metastatic liver malignancies, as well as trauma. Recent advances in hepatic resection techniques along with improvements in anesthetic and critical care have dramatically improved the related morbidity and mortality rates [1-16]. The two most common major complications of hepatic resection are biliary leakage and bleeding. Currently, there is no single surgical device that adequately combines efficient haemostasis, safety for the adjacent vital structures and speed during hilar dissection and parenchymal division.

The purpose of this study was to present our novel 3ST for major hepatectomies and compare it with our standard RFA-assisted technique (published earlier) [17,18]. Although named as 3ST, this is more referring to the combination of 3 separate dissecting tools: the use of Saline-Cooled (SC) radiofrequency coagulation device (TissueLink Medical, Inc.), the Ultrasonic Aspirator (UA) (Misonix FS1000-RF, Surgical Aspirator) in hilar dissection/"glissonean" approach, and RFA (Cooltip RFA System, Valleylab) for hepatic parenchymal transection.

Methods

Patients

All patients were treated at the First Department of Surgery, University of Athens Medical School, Greece. From January 2006 through October 2008, 77 patients were enrolled in this prospective study. Patients were divided into two groups: group A: RFA-assist-

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ed liver resection; and group B: 3ST. The data for group B (3ST) were prospectively collected and compared to the already collated RFA patient group. The principle surgeons performing the procedures were the same for the RFA and 3ST approaches. The mean patient age of group A and B was 66.4 years (range 54-78) and 65.5 years (range 49-81), respectively. A number of clinical, surgical and disease characteristics that could potentially affect intraoperative blood loss were noted. Based on this, the investigated parameters included the amount of blood transfused, the necessity of the Pringle maneuver, the time duration required for parenchymal division, and postoperative morbidity and mortality. In group A, 38 patients underwent 41 RFA-assisted liver resections, in which 19 metastatic tumors, 17 hepatomas, and 4 cholangiocarcinomas were resected. The major RFA-assisted liver resections included 5 extended left, 11 left, 14 right and 19 atypical hepatectomies. In group B, 39 patients underwent 41 hepatectomies using the 3ST, in which 16 metastatic tumors, 15 hepatomas, and 5 cholangiocarcinomas were removed. In the 3ST group we recorded 12 left, 16 right and 5 left extended and 12 non-typical hepatectomies (Table 1).

RFA-assisted liver resection

The method of RFA-assisted liver resection has been described in our previous publications (Figure 1) [17,18].

Three Surgeon Technique (3ST)-assisted liver resection

The procedure described herein takes advantage of well established techniques concerning the inflow and outflow control, as well as liver parenchyma transection. Mainly with the 3ST one can achieve hepatotomies with safety and efficacy in a timeless and bloodless manner aiming at the inflow control as early as possible in the operation with parallel preservation of the integrity of the biliary tree by successfully obtaining the pedicle or the so called posterior intrahepatic or "Glissonean" approach whenever this is needed. The anterior approach (especially when dealing with big right-sided tumors or posterior-sided tumors abutting the inferior vena cava or near the hepatocaval confluence, as well as tumors of the hilar area) could also be easily facilitated with our proposed technique. Thus, with 3ST one can obtain faster and bloodless gross hepatic parenchyma transection whenever needed and easily establish at the same time the more delicate inflow and outflow control by utilizing either the anterior or the posterior approach, all at the same operation. This does not mean that the aforementioned technique could not be used during the conventional approach but that the technique gives a greater impact with the anterior and posterior methods. In this way the surgeon can individualize the operative strategy according to the needs of the patient given the specific circumstances.

Although the technique is named the "3ST", this is more referring to the use of 3 separate dissecting tools by two surgeons - the Tissue Link, the Misonix and the RFA tools. Although the Tissue Link can be considered as a second RFA device, the superficial co-

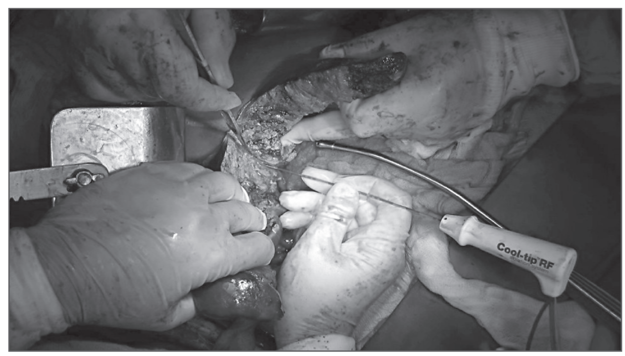

Figure 1. Radiofrequency ablation (RFA) assisted liver resection. The "open book" modification for the RFA liver parenchymal transaction.

Table 1. Statistical comparison of patient/tumor demographics, intraoperative and postoperative outcomes for RFA-assisted and 3ST groups

	RFA-assisted	*3ST*	*t-value/x^2*	*p-value*
Patients (n)	38	39		
Lesions (n)	42	41		
Resections (n)	41	41		
Age (years) ±SD	66.4±10.2	65.5±9.9	0.393 (t-value)	0.696
Males (n)	27	22	1.783 (x^2)	0.182
Females (n)	11	17	1.783 (x^2)	0.182
Tumor size (cm) ±SD	4.91±1.19	5.32±1.33	-1.424 (t-value)	0.159
Cirrhotics (n)	15	14	0.105 (x^2)	0.746
Metastatic tumors (n)	19	16	0.625 (x^2)	0.429
Hepatocellular (n)	17	15	0.312 (x^2)	0.576
Cholangiocarcinoma (n)	4	5	0.098 (x^2)	0.754
Left lobe (n)	11	12	0.031 (x^2)	0.861
Right lobe (n)	14	16	0.142 (x^2)	0.707
Left lobe extended (n)	5	5	0.001 (x^2)	0.965
Non anatomical (n)	19	12	2.959 (x^2)	0.085
Time (min) ±SD	90.49±23.34	77.52±17.45	2.767 (t-value)	0.007
Pringle (n)	3	0	3.204 (x^2)	0.073
Preoperative Ht ±SD	36.2±3.6	35.8±3.5	0.494 (t-value)	0.623
Postoperative Ht ±SD	30.9±3.2	31.1±3.1	-0.279 (t-value)	0.781
Patients transfused (n)	28	13	5.568 (t-value)	0.016
PRBCs transfused ±SD	1.7±0.8	0.6±0.4	7.661 (t-value)	<0.001
Complication	8	7	0.118 (x^2)	0.731
30-day mortality	0	0		–

RFA: radiofrequency ablation, 3ST: 3 surgeon technique, min: minute, PRBCs: packed red blood cells, Ht: hematocrit, SD: standard deviation agulation provided is quite different from the RFA tool, which has a much wider coagulative area.

The main principle of this technique is to combine 3 already time-tested methods of resecting the hepatic parenchyma. The secondary surgeon assisting from the left side dissects the liver parenchyma using the RFA cool tip electrode and the Tissue Link device alternatively, while the primary surgeon divides the liver by operating the Misonix Surgical Aspirator System (Figure 2). The secondary surgeon starts by dissecting the hepatic parenchyma at the line of transection by operating the RFA cool tip electrode (precoagulative technique). The RFA needle electrode is inserted in the hepatic parenchyma, initially close to the surface and subsequently deeper. Hemostatic ablation of the liver tissue is achieved usually in less than 1 min. Accordingly both primary and secondary surgeons are dissecting the hepatic parenchyma using the Misonix Surgical Aspirator System and the Tissue Link device, respectively, while the RFA cool tip electrode is inserted in the nearby area. During parenchymal coagulation and dissection, the hepatic lobe or segment to be resected is gently retracted by the assistant surgeon in order to separate the cut surfaces of the liver for optimal exposure (open book technique). This way intrahepatic vessels are clearly visible and safely coagulated before division. When minor hemorrhage occurs the cut surfaces are approached and pressed together in order to enhance the ablation effect. In addition, the pressure of the liver parenchyma decreases blood supply to the ablated zone, thereby eliminating the heat-sink phenomenon.

With this triple combination we manage in a safe, speedy and bloodless manner to divide most of the hepatic parenchyma with no need to decide on which haemostatic technique to use, unless it is for major portal triads and hepatic veins. These structures are always dissected by Misonix, ligated with 3.0 silk sutures and sharply divided afterwards.

There are two major benefits from this technique. Firstly, easy bloodless precoagulation by RFA Cool Tip of the liver parenchyma, and, secondly, speedy dissection using the Tissue Link and the Misonix. These attributes are required even more so during atypical hepatectomies. In addition to the above, it is important to mention that there is no necessity to use the Pringle maneuver at any time when using the technique.

Close to the hilar and hepatocaval confluence areas, where major vascular and biliary structures have to be protected, as well as close to major intrahepatic portal triads and hepatic veins radicles (especially in cases with tumors abutting the aforementioned structures), there is less need for the use of RFA cool tip electrodes. In these instances it is well publicized that RFA can cause portal vein thrombosis as well as severe complications secondary to thermal injury to the biliary tree, hilar structures and hepatic veins. The liver parenchyma in these areas is dissected safely using the Misonix device, identifying intraparenchymal vascular anatomy in a speedy and safe manner, so a decision on haemostatic technique could be made based on the vessel size (Figure 3).

The technical aspects vary with instruments with the Tissue Link device used here capable of coagulating and dividing dissected vessels 3 mm or smaller. Vessels from 3 to 5 mm have to be controlled with titanium clips and larger vessels and portal triads are controlled with 3-0 silk ties in continuity and divided sharply. Intraoperative ultrasonography is carried out at the end of the procedure in all cases to discover any possible portal vein thromboses and to assess hepatic venous outflow. Central venous pressure is maintained at a low level (< 5 mm Hg) to avoid backflow bleeding and to facilitate better liver tissue manipulation. To prevent air embolism, the hepatic resection is done with the patient at 15-degrees in the Trendelenburg position. At the end of each procedure closed suction drains are placed selectively. It is important to mention that there is no necessity to use the Pringle maneuver at any time when using the 3ST technique.

Statistical analysis

Common statistics were applied in order to estimate the significance of the results. Student's t-test, chi square test, Mann-Whitney non-parametric test, and the Fisher's exact test were used as appropriate, and the differences were considered significant with $p < 0.05$.

Results

There was no difference in age, gender, tumor size, cirrhotic status (Child A & B grade only, with equal numbers in each group), indication for surgery, or surgical procedure between groups A and B (Table 1). Twenty-eight patients (73.7%) in group A and 13 (33.3%) in group B received a transfusion, with an average of 1.7 and 0.6 units of red blood cells, respectively (Table 1). These differences were statistically significant ($p=0.016$ and $p<0.001$, respectively). The Pringle maneuver was necessary in 3 cases in group A but in no case in group B. The mean length of time required for parenchymal dissection was 90.49 min in group A and 77.52 min in

Figure 2. Intra-parenchymal approach of the inflow liver vasculature, achieved by Misonix dissection of the perihilar area.

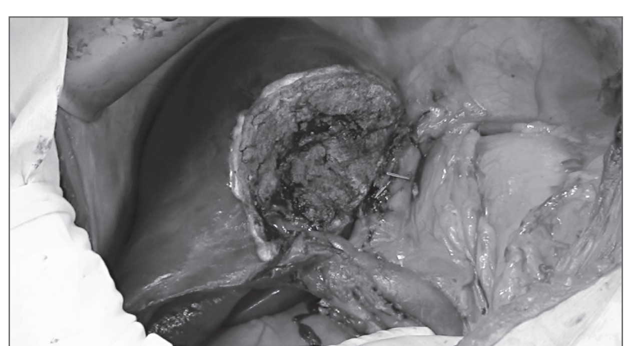

Figure 3. Bloodless complex surgery achieved by the 3ST technique. Non-anatomical left extended hepatectomy for left lobe hepatoma.

group B, which was statistically significant (p=0.007). Histology revealed microscopically R0 resection margins in all the cases in both groups. *Post hoc* power analysis showed that, given the size of the 2 study groups (38 and 39 patients) and the proportions of those receiving a blood transfusion, the statistical power of the study reached 93.2% at a significance level of 0.05.

Discussion

Hemorrhage is a significant contributor to morbidity and mortality in major liver resections. It is also well known that in cases of malignant tumors, perioperative administration of blood affects not only the disease free survival of the hepatectomized patient but also the overall survival. Blood transfusions also carry the risk of transmission of infectious diseases [19-24].

This study compared two modern methods of parenchymal dissection: RFA assisted liver resection and the 3ST. We compared the amount of packed red blood cells (PRBCs) transfused, the necessity for the Pringle maneuver, the length of time needed for parenchymal transection and the postoperative morbidity and mortality. Even though hepatectomy can be performed without any vascular control, the use of inflow and outflow control can result in very low blood loss which can greatly benefit the patient. A significant number of methods of hepatic vascular approach and control of inflow and outflow have been described [25-33]. The standard extrahepatic hilar approach involves the dissection of the appropriate branch of the portal vein, hepatic artery and the hepatic duct outside the liver parenchyma [34-37]. This conventional approach was considered essential in reducing blood loss [38]. However, careless mobilization of the hemiliver may lead to excessive bleeding. Recognition of the portal triad is often quite complex and high division close to the porta hepatis may be required. In this instance, misidentification and ligation of the incorrect vessels may devascularise the healthy remnant hepatic tissue and this can be catastrophic when major resections are performed.

The intrahepatic approach represents an alternative method of vascular control and was first described as the "anterior intrahepatic approach" by Tung [39]. The original technique is usually performed with direct dissection through the liver parenchyma to the inflow and outflow area to be resected. There is no other vascular control (extra hepatic) and the approach carries the advantage of minimal risk of incorrect ligation of vessels and bile ducts. Control of the intrahepatic portal triad was achieved by hepatotomy near the corresponding portal pedicle but, if not performed quickly, bleeding could be substantial from the transection surface. The identification of the hepatic fissures may also be problematic as perfusion of the hepatic segments remains uniform during transection [40]. By using the 3ST we could easily, in a timeless and bloodless manner, obtain the necessary inflow and outflow control early in the operation, thus facilitating the aforementioned approaches without compromising at the same time the resectional procedure.

Many surgeons, aiming at diminishing the amount of blood loss, perform the Pringle maneuver before making a hepatotomy. However, it places the patient at a high risk of liver damage due to ischemia and remains a significant prognosis-affecting factor [25-31]. By using the "Two-surgeon technique", Aloia et al. described how the Pringle maneuver could be avoided [41]. In their technique the primary surgeon dissects the hepatic parenchyma operating the Tissue Link device (precoagulative technique) and the secondary surgeon dissects the hepatic parenchyma from the patient's left side using the Misonix Surgical Aspirator System. Based on this technique the intraparenchymal approach of the portal triads could be straightforwardly obtained. This is also easily achievable in a faster and bloodless way using our 3ST. The main difference is the early use of the RFA Cool Tip electrode in the planned gross resection with subsequent concomitant use of the Tissue Link and Misonix.

An alternative approach is the posterior intrahepatic approach using the Glissonean sheaths [42-46]. This technique permits an intraparenchymal vascular approach, performing dissection along the sheaths around the portal triads and provides access to the main trunk sheaths supplying an entire hemiliver. This approach can easily be achieved using the 3ST while a further dissection within the sectorial divisions is possible. Positioning vascular clamps or bulldog clamps to the encountered vascular structures allows identification of the devascularised segment(s) and then, the sheath may be ligated [47].

The hepatic veins may also be approached and ligated within the liver substance utilizing the same 3ST technique. The advantage with our technique is a reduced risk of damaging veins near their origin at the inferior vena cava (IVC) where hemorrhage may be considerable and not easily manageable [38]. Using a completely bloodless method by clamping the inflow allows ischemic demarcation of the area of liver to be resected and indicates the appropriate line of resection. This parameter has an important role in complex cases like extended or non anatomical major hepatectomies where the segmental inflow ligation may not be possible prior to parenchymal transection and the line of resection must be estimated.

It is well known that the RFA-assisted technique, previously described for liver parenchyma transection, has the advantage of simplicity compared with other transection techniques. The potential disadvantage of coagulating the remnant liver parenchymal tissue (1 cm wide necrotic tissue at the transection margin) which may be critical in cirrhotic patients is well-balanced by the advantage of additional 1 cm coagulative necrotic tissue along the cutting surface. The actual resection margin is increased, which is oncologically significant in some cases of major liver resection for cancers [48,49]. Any concerns existing about the possible thermal injury to the hilar structures and hepatic veins using the RFA-assisted technique for major liver resection are not valid in our technique. Comparing to our previous RFA-assisted technique, we managed to transect the liver parenchyma in less time (p=0.007) and with reduced number of transfused patients (p=0.016) and transfused units (p<0.001). In summary our technique alongside with the intraparenchymal posterior "glissonean" approach of the hilum, makes the portal triad closure unnecessary [50-53]. Also this can reduce the risks associated with parenchymal transection in the perihilar region by accidental injury to the vasculature, especially in the presence of aberrant or accessory hepatic vessels. Due to the early recognition of the contralateral biliary ducts, the surgical injury is eliminated as well. Alternatively, combining our technique with the anterior approach we can easily, early in the operation, and, in a bloodless way, obtain intraparenchymal inflow and outflow control without the need for the extrahepatic portal triad control. This facilitates the resection of major, mainly right, and, posteriorly sided tumors or tumors abutting the hepatocaval confluence.

Hilar dissection in a cirrhotic liver is more difficult because of the surrounding fibrotic tissue, potentially deranged clotting, and the increased vulnerability to ischemia. In these instances the advantages of the 3ST are even more relevant. Additionally, vascular inflow occlusion (Pringle maneuver) which is widely used during hepatotomies and liver parenchymal resection can also be avoided with the presently proposed 3ST approach. Lastly, the precise 1 cm zone of coagulative necrosis (offered by the use of the RFA Cool Tip in the 3ST), in association with safely performed vascular control in complex and major liver resections (massive or multiple liver tumors), may allow for a transection plane that is relatively close to the tumor and this can be achieved without jeopardizing the need for clear resection margins.

Conclusions

Our study suggests that multimodality approaches, which individualize the use of different means and techniques according to the tasks of bloodless liver tissue dissection, contain several rewards. The main advantages are improvement in obtaining a bloodless field, reduced need for blood transfusions and a time-efficient procedure.

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