Radiofrequency (RF)-assisted resection techniques are associated with minimal blood loss providing safe hemostasis of the transected liver parenchyma. Different RF-assisted liver resection techniques have been developed. The presented RF technique is the sequential coagulate-cut liver resection technique (“The Belgrade technique”) and the difference from other techniques is the way the electrode is used. A coagulate-cut liver resection cycle can be described as a process of creating a 30-mm long and 6-8 mm wide cylinder of coagulated and desiccated liver tissue by applying RF energy through the non-insulated tip of the electrode inserted into the liver parenchyma and then dividing the coagulated tissue by surgical scalpel or scissors.

From January 2001 to January 2014, 830 RF-assisted liver resections were performed for various indications at the HPB unit of the Clinic for Digestive Surgery, Clinical Center of Serbia, Belgrade. Among 830 liver resections, 470 resections were performed in 383 patients with colorectal cancer liver metastasis. Sixty-six patients experienced repeated liver resection ranging from a second to a fifth resection. The majority of patients had bi-lobar spread of the disease before the first liver resection was performed. No difference was found in the postoperative morbidity between the patients after the first, the second and the third liver resection ($F=0.168$; $p=0.846$). 90-days mortality was 5.7% after the repeated liver resections and 2.5% in patients with one liver resection ($X^2=2.278$; $p=0.165$). Single HPB unit experience has demonstrated that RF-assisted liver resection technique is feasible, safe and effective procedure in the management of patients with CRC liver metastasis.

Key words: radiofrequency, liver resection, metastasis, colorectal cancer
segmental pedicles during the transection is facilitated and temporary clamping is possible; (f) ablation of the resected liver rim is at least 5mm decreasing the incidence of transection site recurrence.

Several authors reported that RF-assisted resection may induce severe liver damage. However, these reports are related to other RF-assisted techniques, like it is the case with the blind precoagulation of the entire liver mass along the resection line, or when RF energy is applied near the main bile ducts, or when the Pringle maneuver was used. Previous reports have indicated that the Pringle maneuver in RF-assisted liver resections was unnecessary, as only the precoagulated, devitalized, liver tissue is cut. Moreover, hepatic blood flow occlusion is associated with a significant increase in the coagulation area, leading to more extensive tissue necrosis. Maintenance of the normal blood flow during liver resection is becoming increasingly important as liver surgeons are nowadays operating on already damaged livers having suboptimal liver function (chronic inflammation due to steatosis/obesity and metabolic syndrome, chemotherapy-induced liver damages, cirrhosis, etc).

Widely used vascular occlusion techniques, although effective in reducing blood loss, have been shown to compromise hepatic functional reserve in livers with a preexistent disease. Although a recent, randomized trial demonstrated an earlier recovery of the postoperative liver function after hemihepatic vascular inflow occlusion compared with the Pringle maneuver, it is technically more demanding and potentially associated with more bleeding in diseased livers.

Recent meta analysis confirmed the advantage of RF-assisted techniques in reducing blood loss. However, RF-techniques may increase the rate of both abdominal abscess and bile leak. It has been concluded that future well-designed randomized clinical trials are needed to further investigate the efficacy and safety of RF devices in liver resection.

The RF-assisted sequential coagulate-cut liver resection technique ("Belgrade technique")

Under general anesthesia a J incision without opening of the diaphragm is performed. A Thompson retractor is used to ensure good exposure of the liver. The patient is in an anti-Trendelenburg position (15° head up). The tumor-containing liver lobe is mobilized in a standard way to the extent necessary for the intended resection, avoiding unnecessary liver mobilization and manipulation. Intra-operative ultrasound, assisted by bimanual palpation, is always performed to determine the accurate position, extent, number of the tumors and their relation to the hepatic veins and glissonian pedicles. Infow and outflow occlusion of the liver vessels, low CVP anesthesia, and topical hemostatic agents are not used during the transection of the liver parenchyma.

The upper and lower surface of the liver are marked with diathermy in order to establish a roadmap for the resection. Liver transection is started by inserting the entire non-insulated tip of the electrode into the liver parenchyma. The tip of the electrode is inserted parallel to the liver surface 2-3 mm beneath the liver capsule and along the marked lines. RF energy is applied by rapidly increasing the output to maximum power, which, when using the 30-mm tip electrode, produces an approximately 30-mm-long and 6-mm-wide cylinder of pale, desiccated liver tissue in <20 s. Coagulative desiccation progresses upwards, from the inserted non-insulated tip of the electrode, to the liver surface causing the tissue to change to a pale color. After the cylinder of desiccated liver tissue is achieved, with the electrode still in place, the desiccated tissue is cut with a surgical scalpel all the way to the non-insulated tip of the electrode (only the upper part of the desiccated cylinder is cut). The next placement of
the non-insulated tip of the electrode is at the bottom of the remaining desiccated liver parenchyma bellow the electrode (the remaining half of the desiccated cylinder; in this way the next cycle is more rapid since the tissue has already been desiccated). This markedly increases the spread of the transection. A coagulate-cut cycle can be described as a process of creating a 30-mm long and 6-8 mm wide cylinder of coagulated and desiccated liver tissue by applying RF energy through the non-insulated tip of the electrode inserted into the liver parenchyma and then dividing the coagulated tissue by surgical scalpel or scissors. Essentially, the non-insulated tip of the electrode is used in the same way the tip of the CUSA is used. Division of the liver parenchyma always progresses from the intact or cut surface of the liver into the bulk of the liver and from the anterior to the posterior aspect of the liver. Transection of the liver parenchyma is achieved by sequential coagulate-cut cycles always under direct visual guidance regardless of whether we are doing an anatomical or non-anatomical liver resection.

The consequent resection margins consist of coagulated and desiccated, practically welded, liver tissue. Since small blood vessels are occluded during the multiple rapid sequential coagulate-cut cycles, the operative field is practically bloodless. All relevant intraparenchymal structures can be visually identified without prior thermal damage and subsequently divided or preserved. (Figure 1a-d) Thermal energy spread is limited to the resection area and the surrounding liver parenchyma maintains a normal temperature as demonstrated by the thermal vision. (Figure 2)

**GRAPH 1**

TNM STATUS OF THE PRIMARY TUMOR AMONG CRC LIVER METASTASIS PATIENTS HAVING REPEATED LIVER RESECTIONS

**GRAPH 2**

DISTRIBUTION OF LIVER METASTASIS IN PATIENTS HAVING REPEATED LIVER RESECTIONS

**GRAPH 3**

PERIOPERATIVE MORBIDITY IN PATIENTS HAVING REPEATED LIVER RESECTIONS

the non-insulated tip of the electrode is at the bottom of the remaining desiccated liver parenchyma bellow the electrode (the remaining half of the desiccated cylinder; in this way the next cycle is more rapid since the tissue has already been desiccated). This markedly increases the spread of the transection. A coagulate-cut cycle can be described as a process of creating a 30-mm long and 6-8 mm wide cylinder of coagulated and desiccated liver tissue by applying RF energy through the non-insulated tip of the electrode inserted into the liver parenchyma and then dividing the coagulated tissue by surgical scalpel or scissors. Essentially, the non-insulated tip of the electrode is used in the same way the tip of the CUSA is used. Division of the liver parenchyma always progresses from the intact or cut surface of the liver into the bulk of the liver and from the anterior to the posterior aspect of the liver. Transection of the liver parenchyma is achieved by sequential coagulate-cut cycles always under direct visual guidance regardless of whether we are doing an anatomical or non-anatomical liver resection.

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Single HPB unit experience in RF liver resections for CRC liver metastasis

From January 2001 to January 2014, 830 liver resections were performed for various indications at the HPB unit of the Clinic for Digestive Surgery, Clinical center of Serbia, Belgrade. (Table 1) All 830 liver resections were performed using the RF-assisted liver resection technique.

All patients included in the liver resection program met the following criteria: (a) no extrahepatic spread of disease that can not be managed by a curative intent surgery; (b) liver lesion or lesions resectable with adequate (R0) margins; (c) adequate remnant functional liver parenchyma; (d) no obstructive jaundice; and (e) simultaneous operative procedures on other organs is performed when curative intent surgery can be applied.

The preoperative workup of the patients included: (a) accurate liver imaging for planning the extent of resection utilizing multi-detector CT or MRI; (b) the dynamic liver test to assess hepatic functional reserve in patients with large or multiple liver tumors; (c) tumor markers measurement (CEA, Ca19.9); and (d) pre-operative computer-based virtual resection simulation for very compli-
cated cases. Preoperative tumor biopsy was not performed. In all patients, biochemical liver function tests were monitored before and on the first, third, fifth, and seventh days after liver resection. Liver sequestration, liver abscess, subphrenic abscess, bile leakage, sepsis, chest involvement, and postoperative bleeding were considered procedure related complications.

Among 830 liver resections, 470 resections were performed in 383 patients with CRC liver metastasis. Sixty-six patients experienced repeated liver resection ranging from a second to a fifth resection. (Table 2)

Patients having repeated liver resection were mostly 61-70 years old (26) or 51-60 years old (21). The TNM status of the primary tumor in this patients’ population was dominantly T3N1. (Graph 1)

The median time interval between the colorectal surgery and the first liver resection was seven months; ten months was the time interval between the first and the second liver resection and 8 months was the period between the second and the third liver resection.

The total number of liver metastasis was greater at the time of the first liver resection comparing to the later ones. The majority of patients (43.9%) had 2-3 liver metastases at the time of the first liver resection.

The majority of patients had bi-lobar spread of the disease before the first liver resection was performed. (Graph 2)

Preoperative chemotherapy was given to only 24.2% of patients before the first liver resection. The adjuvant chemotherapy was given to 22.7%, 30.3% and 47.1% of patients following the first, the second and the third liver resection respectively.

Statistically significant difference in the postoperative hospital stay of patients after the first, the second or the third liver resection was not found (F=0.254; p=0.784). No difference was found in the postoperative morbidity between the patients after the first, the second and the third liver resection (F=0.168; p=0.846). (Graph 3) 90-days mortality was 5.7% after the repeated liver resections and 2.5% in patients with one liver resection (X²=2.278; p=0.165).

Conclusion

Single HPB unit experience has demonstrated that RF-assisted liver resection technique is feasible, safe and effective procedure in the management of patients with CRC liver metastasis. This procedure can be performed in patients requiring repeated liver resections as well.

SUMMARY

RADIOFREKVENTNA RESEKCIJA JETRE KOD METASTAZA KOLOREKTALNOG KARCINOMA

Radiofrekventnu (RF) resekciju jetre karakteriše minimalan gubitak krvi i sigurna hemostaza reseciranog parenhima jetre. Razvijene su različite RF tehnike resekcije jetre. Predstavljena RF tehnika je tehnika sekvencijalne ablacije i reseciranja parenhima jetre poznatija kao „Beogradska tehnika” i razlikuje se od drugih tehnika prema načinu kako se koristi elektroda. Ciklus ablacije i reseciranja dela parenhima jetre može se opisati kao process formiranja 30mm dugog i 6-8 mm širokog cilindra desnokovanog tkiva jetre primenom RF
energije koja se u tkivo aplikuje preko aktivnog tj otkrivenog dela elektrode; potom se kroz ovo tkivo parenhim jetre razdvaja bilo skalpelom bilo makazama.

Od januara 2001. do januara 2014. godine urađeno je 830 RF resekcija jetre za različite indikacije na odeljenju za HPB hirurgiju Klinike za digestivnu hirurgiju Kliničkog centra Srbije. Od 830 resekcija, 470 je urađeno kod 383 bolesnika sa metastazama kolorektalnog karcinoma. Kod 66 bolesnika urađena je ponovljena resekcija jetre (od dve do pet resekcija). Većina bolesnika je imala bilobarnu distribuciju metastatske bolesti pre prve resekcije jetre. Nije nađena razlika u postoperativnom morbiditetu kod bolesnika posle prve, druge ili treće resekcije jetre. Nije nađena razlika u postoperativnom mortalitetu kod bolesnika posle prve, druge ili treće resekcije jetre (F=0.168; p=0.846). Postoperativni mortalitet 90 dana od operacije je bio 5.7% posle ponovljene resekcije i 2.5% kod bolesnika koji su imali samo jednu resekciju jetre (X²=2.278; p=0.165). Iskustvo individualnog HPB centra pokazuje da je RF resekciona tehnika izvodljiva, bezbedna i efikasna procedura u lečenju bolesnika sa metastazama kolorektalnog karcinoma.

Ključne reči: radiofrekventna, resekcija jetre, metastaze, kolorektalni karcinom

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