The retrohepatic inferior vena cava is its section approximately 7 cm long in the majority of patients and limited by the phrenic veins above and the right adrenal vein below (1). It lies entirely within the „bare area”, the part of the liver lacking a capsule and totally circumscribed by hepatic suspensory ligaments (1). In this area the inferior vena cava has a direct contact with the posterior portion of the liver (1). The inferior vena cava joins the right atrium approximately 3 cm above the superior end of the retrohepatic fragment (1).

The venous blood of the liver drains into the retrohepatic inferior vena cava in an anterior-to-posterior and inferior-to-superior direction by three major hepatic veins and their tributaries (1). The right hepatic vein drains segments VII, VI, VIII and V and the inferior portion of segment IV (1). Its intraparenchymal section is usually single and runs along a plane between segments VIII with V and VII with VI (1). This plane is called the right portal fissure. The left hepatic vein lies in the superior part of the left portal fissure. Its intraparenchymal section is approximately 8 to 10 cm long and drains the entire lateral sector of the left lobe (segments II and III) and a variable part of its medial sector (segment IV) (1). The middle hepatic vein is approximately 12 cm long (1). It lies in the middle portal fissure that is a border between the right and the left liver segments. This vein drains the most of the medial sector of the left liver portion (segment IV) and a part of the anterior-medial sector of the right portion (segment VIII) (1). Its intrahepatic section runs along the interlobar plane (Cantlie’s Line) appointed schematically between the gall-bladder fossa and the inferior vena cava (1). In approximately 85% of cases, the left and middle hepatic veins unite before emerging from the liver parenchyma and form a single extraparenchymal trunk that is approximately 1 cm long or less and joins the inferior vena cava, while in approximately 15% of cases three separate, major hepatic veins enter the inferior vena cava (1). The major hepatic veins have both long intraparenchymal sections and short extraparenchymal segments and join the anteromedial and anterolateral surfaces of the inferior vena cava only a few centimeters below the atroicaval junction (1).

Three hepatic veins and the retrohepatic vena cava in English are named the juxtahepatic veins.

The suspensory ligaments of the liver are: the falciform and coronary ligaments superiorly and the triangular ligaments that extend caudally along the right and left lateral aspects of the liver bare area and cross transversely at the level of the right adrenal vein, forming the lower border of the bare area (1). They are composed of peritoneum and endoabdominal fascia and tether the liver to the diaphragm and retroperitoneum (1). They support the liver weight and prevent traction on the extraparenchymal hepatic veins (1). Because of their circumscription of the bare area which contains the retrohepatic inferior vena cava and the extraparenchymal sections of the hepatic veins, these ligaments have significant role in controlling hemorrhage from the injured hepatic veins and retrohepatic inferior vena cava (1).

All injuries of the hepatic veins and retrohepatic inferior vena cava that can cause
hemorrhage into the abdominal cavity or into the chest, have two separate elements: the first is the venous injury itself, which may occur anywhere along the intraparenchymal or extraparenchymal portion of the hepatic veins and the second is the rupture of tissues around the vein that would be able to confine or contain the hemorrhage from the lacerated vein (1). The structures potentially able to confine juxtahepatic venous hemorrhage are: the liver parenchyma and capsule, enclosing the intraparenchymal sections of the veins and the connective tissue, diaphragm and hepatic suspensory ligaments, surrounding the extraparenchymal venous portions (1). Free bleeding occurs only when a breach of those containing tissues is associated with a venous laceration, while juxtahepatic venous injuries in which the containment structures have not been critically disrupted or in which they maintain sufficient integrity to tamponade the venous injury are not associated with severe free bleeding and are not serious clinical problems providing they are untouched during the operation (1).

There are two types of injuries of the hepatic veins and retrohepatic inferior vena cava: type A and type B (1). Type A consists of wounds in which the hepatic venous injury is intraparenchymal and that are associated with disruption of the liver parenchyma and capsule (1). In this type of injuries bleeding directly through the disrupted liver parenchyma is dominant and hemorrhage intensity can be limited by the untouched suspensory ligaments or increased due to their rupture (1). Type A of hepatic venous injuries may be associated with wounds involving the branches of the portal vein and hepatic artery (1). Type B is represented by injuries in which the venous wound is extraparenchymal and is associated with disruption of the suspensory ligaments, the diaphragm, or both (1). Disruption of the liver parenchyma and capsule may be coexisting, but in this injury pattern bleeding is predominantly around the liver or into the chest rather than through the liver parenchyma (1). Type A is more common (1).

Injuries of the retrohepatic inferior vena cava or hepatic veins should be suspected in patients with a severe liver parenchyma injury when the Pringle manoeuvre fails to control bleeding or when the injury extends to the bare area on intraoperative palpation (2).

It is necessary to remember that unusual presentations can occur, such as a right hemothorax and a pericardial tamponade (3). Profuse venous hemorrhage from behind the right liver lobe, into the lesser sac, or posterior to the liver hilum may also suggest injury of the retrohepatic inferior vena cava, while hemorrhage near the diaphragm may suggest injury to either the inferior vena cava, suprahepatic or retrohepatic, or hepatic veins (3). Facing injuries of the hepatic veins and retrohepatic inferior vena cava, the same as facing liver trauma, a surgeon has various operative strategies to use.

**SURGICAL TREATMENT OF INJURIES OF THE HEPATIC VEINS AND RETROHEPATIC INFERIOR VENA CAVA**

**Total vascular exclusion**

This method includes the occlusion of the hepatoduodenal ligament and the occlusion of the infrahepatic and suprahepatic inferior vena cava. Unfortunately, it causes a sudden drop of venous return and profound hypotension, requiring intensive transfusions to maintain adequate cardiac output in previously hypovolemic patients with decreased venous return to the right atrium (2). This manoeuvre may be useful when juxtahepatic venous injuries can be repaired relatively quickly (4). Total vascular exclusion allows to repair the injured veins in patients in satisfactory general condition and without significant intra-vascular volume depletion (this attempt may be performed only in reference centers), but in a majority of patients it leads to cardiac arrest due to severe hypovolemia (1). The recommended strategy after hepatic vascular exclusion is observing the patient’s response in systemic circulation and the injured veins may be repaired if there is no significant hemodynamic effect (4). During vascular exclusion of the liver all bleeding vessels can be controlled and resectional debridement or liver resection can be also performed with minimal blood loss, but after removing the clamps attention should be paid to parenchymal bleeding (5). The advantage of this method is also a possibility of achieving it through the abdominal incision, without the need for the lateral thoracotomy or sternotomy (6).
Temporary veno-venous by-pass

This procedure involves a cannulation of the external iliac vein through the major saphenous vein (usually on the left side) and a cannulation of the inferior mesenteric vein (more rarely a direct cannulation of the portal vein). In effect blood flows through the centrifugal vortex pump into the left axillary vein or more rarely the left internal jugular vein through the inserted cannulas. The occlusion of arterial and venous hepatic inflow is secondary to Pringle manoeuvre (clamping the hepatic artery and portal vein), the inferior vena cava is occluded suprahepatically and infrahepatically above the level of the renal veins and the portal system is drained through a cannula inserted into the inferior mesenteric vein (2). This system is the same as used during liver transplantation and allows for total vascular isolation of the liver with control and repair of the injured vessels, maintaining simultaneously venous return and mesenteric perfusion (2, 4, 7). It enables to perform all necessary procedures, it does not cause arrest of venous return from the lower part of the body and in effect does not lead to hemodynamic instability. In our opinion this method may be used successfully in patients with injuries of the retrohepatic inferior vena cava and hepatic veins. Unfortunately, it is available only in liver transplantation centers in practice.

Atriocaval shunt

In articles related to management of severe liver trauma a possibility of total hepatic vascular isolation by a temporary atriocaval shunt extending from the right atrium to the vena cava is still reported. This procedure involves the insertion of a chest tube into the inferior vena cava extending from the right atrial appendage inside the inferior vena cava to the level just above the renal veins with simultaneous occlusion of the hepatoduodenal ligament, what results in total isolation of the liver from the systemic circulation. Today those relations must be treated only as sporadic reports and this manoeuvre is performed probably by nobody. Besides, there is a possibility of the ineffective atriocaval shunt due to incorrect performance and anatomical conditions (3). In addition, this manoeuvre is associated with the risk of causing additional damage and air embolism (3). The atriocaval shunt is associated with the high mortality too (3, 8-11). This procedure is also time-consuming, much more than total vascular isolation using a temporary veno-venous by-pass.

Direct venous repair

Venous lacerations may be also repaired directly without an atriocaval shunt, after previous division of the hepatic parenchyma and exposing the injured vessels (11, 12, 13). That management is possible very seldom due to patient’s severe condition and should be performed only in surgical wards specialized in liver surgery. Caval injuries may be repaired with a continuous polypropylene 4-0 suture, while the intrahepatic branches of the hepatic veins may be ligated, the same as the intrahepatic biliary ductal branches and other blood vessels (13). All necrotic tissues must be debrided (13). Another possibility, appropriate for small injuries of the suprahepatic or retrohepatic inferior vena cava which can be controlled with a finger, is sewing beneath the finger with a needle large enough to apply the suture with one motion (3). The smaller vessels and additional veins joining the vena cava may be ligated, clipped, tied up or sutured. Direct venous repair is necessary if other available strategies are unable to stop bleeding from the retrohepatic inferior vena cava and hepatic veins (1). It is also necessary to remember that severe injury of the liver parenchyma associated with a laceration of the hepatic veins requires almost in every case not only venous repair, but also liver resection, of course usually during a relaparotomy after previous placement of perihepatic packing and stabilizing a patient’s condition.

Anatomic liver resection

Immediate anatomic liver resection is not a commonly used method of management of bleeding from the injured hepatic veins (1). It is rather indicated in case of severe injury of the hepatic parenchyma associated with the presence of necrotic tissues, which can however coexist with hepatic venous injuries. These procedures should be never performed in patients in critical general condition, but during a planned relaparotomy, in hemody-
namically stable patients, with corrected aci-
dosis and without coagulopathy.

Perihepatic packing

In case of juxtahepatic venous injuries peri-
hepatic packing is a solution that is more com-
monly used and may be performed in every hospital (14). It is often used when liver resec-
tion is impossible due to severe patient’s condi-
tion (14). This procedure is very successful
management with survival rate approximate-
ly 60%, more successful than direct venous
repair (9). It consists of compression of the site
of juxtahepatic venous injury with laparotomy
pads. The amount of pads necessary to achieve
compression may be variable, but usually a
few or over a dozen are used. After placing the
pads the abdomen ought to be closed without
any drainage. The last pad must not be with-
drawn through the wound or a separate hole.
Withdrawing a drain or leaky suturing the
wound decreases efficiency of perihepatic pack-
ing. Correctly performed perihepatic packing
allows to control almost all liver venous hem-
orrhage from the liver (5, 7). Its early use in-
creased the amount of survivors who would
probably die during for example the attempt
of performing an atrio caval shunt (9).

Omental packing

It is a quite efficient strategy that allows to
control bleeding from venous injuries, but that
effect is related only to relatively small vessels
(12, 15). It seems to be a method more effective
than direct venous repair, at least in cases of
transparenchymal liver venous hemorrhage
(type A) (1). An omental pack inserted into the
damaged area is characterized by the ability
to tamponade deep intreahepatic venous bleed-
ing (16).

Liver transplantation

Liver transplantation after liver trauma
may be a life-saving procedure, if all other
strategies fail to control bleeding (2). This
management can be performed only in liver
transplantation centers. However, it is neces-
sary to remember the fact of lack of donors
while the indications for potential posttrau-
matic liver transplantation are very urgent,
so that procedure is a limited option (2). It is
performed very seldom in patients with inju-
ries of the retrohepatic inferior vena cava and
hepatic veins in practice. A possibility of liver
transplantation as a final solution for irrepa-
rable liver injuries is real, but full of logistical
and ethical problems (4). Successful per-
formance of liver transplantation after hepatic
trauma first requires control of hemorrhage
by total hepectomy of a fragmentated liver
(4). Then a patient must be transferred to a
liver transplantation center and maintained
in the anhepatic state until a donor is avail-
able, but lack of the necessary organ threatens
the patient with death before transplantation
(4). That is why hepectomy with potential
liver transplantation due to severe liver trau-
ma is an option unavailable for the majority
of patients (4). Potential candidates are only
those in whom all other procedures were un-
able to control hemorrhage, or more accu-
rately, in whom the liver has been totally de-
vascularized such that there is no other alter-
native (4).

SUMMARY

Injuries of the retrohepatic inferior vena
cava and hepatic veins are still serious surgi-
cal problems. Except venous injuries associ-
ated with hemorrhage, quite difficult surgical
access and few treatment methods are addi-
tional difficulties. Options of management of
juxtahepatic venous injuries are unfortunat-
ely quite limited because they involve only two
strategies: the first is liver vascular isolation
by one of two available methods (total vascular
exclusion, temporary veno-venous by-pass) and
direct venous repair, while the second is an
attempt to confine bleeding by achieving com-
pression of the hepatic parenchyma and fi-
nally compression of the injured veins. An
additional factor associated with a poor outlook
is usually severe patient’s general condition
with coexisting hypovolemic shock and coagu-
lopathy. After performing efficient perihe-
ptic packing, repair of the injured vessels
(eespecially large) and resectional debridement
may be necessary to perform during the re-
laparotomy. Liver transplantation is rather a
limited option, mainly due to lack of organs
indispensable for urgent transplantation and
cases of its use as treatment of severe juxta-
hepatic venous injuries are sporadic. Tempo-
rary veno-venous by-pass is available only in
liver transplantation centers so it is obvious that successful and final management of juxtahepatic venous injuries is possible only in liver surgery centers, equipped with specialistic devices and having necessary experience in liver surgery. In the lower reference centers a recommended strategy is performing perihepatic packing and transferring a patient to a center experienced with liver surgery. Actually perihepatic packing, especially using gauzes, is thought to be a method ensuring even alternative and much effective management than direct venous repair (1). That is why, basing on the liver anatomy and mechanisms of juxtahepatic venous injuries, a recommended strategy is immediate perihepatic packing and transferring a patient to a liver surgery center in which, during the reoperation performed after hypovolemic shock has been corrected, definite control of the bleeding site by vascular restoration or liver resection is eventually considered.

REFERENCES