

ARE THE IMAGING FINDINGS USED TO ASSESS THE PORTAL TRIAD RELIABLE TO PERFORM LIVING-DONOR LIVER TRANSPLANT?

Os achados de imagem para avaliação da tríade portal são confiáveis para realização do transplante hepático com doador vivo?

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ABSTRACT - Background: A crucial aspect of living-donor liver transplant is the risk imposed to the donor due to a procedure performed in a healthy individual that can lead to a high postoperative morbidity rate. **Aim:** To correlate the pre- and intraoperative hepatic imaging findings of living adult donors. **Methods:** From 2003 to 2008 the medical charts of 66 donors were revised; in that, 42 were males (64%) and 24 females (36%), mean age of 30±8 years. The preoperative anatomy was analyzed by magnetic resonance cholangiography to study the bile ducts and by computed tomography angiography to evaluate the hepatic artery and portal vein. Normalcy criteria were established according to previously published studies. **Results:** Anatomic variations of the bile ducts were found in 59.1% of donors, of the artery hepatic in 31.8% and of the portal vein in 30.3% of the cases during the preoperative period. The magnetic resonance cholangiography findings were in agreement in 44 (66.6%) of donors and in disagreement in 22 (33.3%). With regards to hepatic artery, in all donors the findings of the imaging examination were in agreement with those of the intraoperative period. As to the portal vein, the computed tomography findings were in agreement in 59 (89.4%) donors and in disagreement in seven (10.6%). **Conclusions:** The bile duct anatomic variations are frequent, and the magnetic resonance cholangiography showed moderate accuracy (70%) in reproducing the surgical findings; the computed tomography reproduced the intraoperative findings of the hepatic artery in 100% of donors, and of the portal vein in 89.4% of the cases, thus demonstrating high accuracy (89%).

RESUMO - Racional: Um aspecto crucial do transplante hepático inter-vivos é o risco imposto ao doador, devido ser procedimento realizado em pessoa saudável, com possibilidade de alta morbidade pós-operatória. **Objetivo:** Correlacionar os achados de imagem do pré e intra-operatório dos doadores adultos vivos de fígado. **Métodos:** No período de 2003 a 2008 foram revisados os prontuários de 66 doadores. Foram 42 homens (64%) e 24 mulheres (36%), com média de idade de 30 anos (± 8 anos). A anatomia pré-operatória foi analisada através de colangiografia por ressonância nuclear magnética para estudo dos ductos biliares e angiografia por tomografia computadorizada para artéria hepática e veia porta. Critérios de normalidade foram estabelecidos de acordo com estudos prévios da literatura. **Resultados:** Variações anatômicas dos ductos biliares foram encontradas em 59,1% dos doadores; da artéria hepática em 31,8% e da veia porta em 30,3% dos casos no pré-operatório. A colangiografia por ressonância nuclear magnética apresentou achados concordantes em 44 (66,6%) doadores e discordantes em 22 (33,3%). Com relação à artéria hepática em todos os doadores os achados do exame de imagem foram concordantes com os do intra-operatório. Para a veia porta a tomografia computadorizada apresentou achados concordantes em 59 (89,4%) doadores e discordantes em sete (10,6%). **Conclusões:** As variações anatômicas dos ductos biliares são frequentes, com a colangiografia por ressonância nuclear magnética apresentando acurácia moderada (70%) na reprodução dos achados cirúrgicos; a tomografia computadorizada reproduziu os achados do intra-operatório da artéria hepática em 100% dos doadores, e reproduziu os achados intra-operatórios em 89,4% dos casos em relação à veia porta, apresentando acurácia elevada (89%).

INTRODUCTION

Raia *et al.*²² performed the first living-related liver transplant in Brazil, in 1988, using the left hepatic lobe (segments II and III) of an adult donor and transplanting to a pediatric recipient. In 1994, Yamaoka *et al.*²⁸, with experience of over 200 pediatric transplants, reported the first successful living-related liver transplant between adults, and used the right hepatic lobe.

A crucial aspect of this modality of liver transplant is the risk imposed to the donor due to a procedure performed in a healthy individual that can lead to a postoperative morbidity rate up to 21% and mortality of 0.5%¹⁷. One of the causes for these high complication rates is related to many anatomical variations in vascular structures and bile ducts that are not identified in the preoperative period¹⁴.

Anatomical variations of the hepatic artery (HA) are usually found in approximately 45% of potential living donors of liver^{13,21,27}. Identifying the origin of the arterial branch that irrigates the segment IV is also very important, since it is paramount to have no damage to lead to regeneration of the left hepatic lobe²⁰. Alterations of the portal vein (PV) are observed in roughly 20% of this population and, although they often do not contraindicate the transplant, they make surgery longer after being identified and demand multiple anastomoses, which increase the risk of thromboses^{10,15}. There is much concern since only about 60% of donors present conventional anatomy of the bile ducts, and the variations pose major technical challenges to perform living-related liver transplant or may even be a contraindication to donation^{12,16,19}.

Hence, broad preoperative knowledge about anatomy of the portal triad elements of donors is required to make the procedure of reconstructing vascular structures and bile ducts easier. Moreover, it reduces postoperative morbidity rates of recipients and enhances quality of graft, safety and selection of the donor when there are many candidates available^{4,24}. To this end, computed tomography angiography (CT angiography) and magnetic resonance cholangiography (MR cholangiography) are used as preoperative examination to analyze anatomical variations in the portal triad^{4,19,24}.

The objective of this study was to correlate the pre- and intraoperative hepatic imaging findings of living adult donors.

METHODS

The medical charts of 66 living-related liver transplant donors at the Hospital Beneficência Portuguesa de São Paulo were retrospectively assessed in the period 2003 to 2008. Forty-two

(64%) were males and 24 (36%) females, age range of 19-50 years and mean age of 30±8 years, and body mass index (BMI) varying between 19.8 and 38.2 kg/m² and mean BMI of 25.7±3.9 kg/m².

The classification used to describe the anatomical variations of bile ducts was proposed by Couinaud⁹; of the HA, by Michels²¹ and of the PV by Akgul *et al.*².

Imaging examination protocol

MR cholangiography

The 1.5 T magnetic resonance device (G.E.[®] Excite HD) and surface coils were used. Patients were asked to fast from 6 to 8 h and were intravenously injected scopolamine butylbromide 20 mg (except for patients with allergy or glaucoma) a few minutes before positioning in the device to reduce peristalsis artifacts.

After localizing sequences, the axial T2-weighted fast spin-echo images were obtained with fat saturation, according to the following parameters: TE/TR of 85/2000-2500 ms, field of view (FOV) of 40 mm and slice thickness of 6 mm at 2 mm intervals. The cholangiographic series were obtained in volume sequences of coronal respiratory-triggered fast-recovery fast spin-echo, with TE/TR of 400/5000-12000 ms and FOV of 38 mm, radial T2-weighted single shot fast spin-echo sequences, centered on the common bile duct, with TE/TR of 400/2000 ms and FOV of 28; in addition, coronal volume sequence using fast imaging employing steady-state acquisition (Fiesta[®]) with minimum TR/TE, slice thickness of 3-3.6 mm and FOV of 38 mm.

Axial T1-weighted gradient echo liver acquisition with volume acceleration (Lava[®]) volume sequence was also obtained in some patients, with minimum TE/TR, thickness of 5 mm and FOV of 40 mm, before and after injection of gadolinium (0.2 ml/kg).

The examination time varied from 20 to 30 minutes and the images were sent to workstations dedicated to manipulation.

CT angiography

The 16- and 64-section multidetectors (LightSpeed – GE[®], Aquilion 16 and 64 – Toshiba[®] and SOMATOM 128 – Siemens[®]) were used after intravenous injection of 75-150 ml of nonionic iodinated contrast through a pump injector at flow rate of 3-5 ml/s, with 1-1.25 mm slices reconstructed at 0.8-1 mm.

The arterial, portal and venous phases were obtained and the latter only in patients with unsatisfactory venous opacification. All series were sent for analysis in dedicated workstations.

Statistical analysis

The Kappa coefficient was applied to study

reproducibility between two qualitative variables, ranging from zero to one. When the coefficient was one, the agreement was considered perfect, while when it was zero, there was no agreement. Moreover, sensitivity, specificity, positive and negative predictive values were calculated, as well as accuracy of the radiological findings as compared to intraoperative observations, which were considered as gold standard. The significance level of 0.05 ($\alpha=5\%$) was used.

RESULTS

As to the biliary tract anatomy of 66 donors included in the present study, only 27 cases (40.9%) had normal anatomy of bile ducts, that is, Type I in the intraoperative cholangiography.

There were anatomical variations in 20 donors (30.3%) in the MR cholangiography and in 39 donors (69.7%) in the intraoperative cholangiography (Table 1).

TABLE 1 - Comparison of the anatomical variations of the biliary tree

Anatomy type by Couinaud	Appearance	Results of MR cholangiography	Results of intraoperative cholangiography
1	Normal anatomy: right posterior duct drains into right hepatic duct, which joins left hepatic duct to form common hepatic duct	69,7%	40,9%
2	Trifurcation of right anterior sectorial duct, right posterior sectorial duct, and left hepatic duct	1,5%	4,5%
3	Right anterior or posterior sectorial duct joins left hepatic duct separately	3%	3%
4	Right anterior or posterior sectorial duct joins common hepatic duct separately	24,2%	40,9%
5	Absence of defined upper biliary confluence, with all sectorial ducts joining separately	1,5%	10,6%
6	Right posterior sectorial duct join cystic duct	0	0

In 19 donors (28.8%) the MR cholangiography showed Type I biliary tract anatomy, but in disagreement with the intraoperative findings, in which two (3%) presented Type II variation, 13 (19.69%) Type IV and four (6%) Type V anatomy.

In 17 (25.75%) donors the preoperative anatomical variations were in agreement with the intraoperative findings. Among them, one (1.51%) donor had Type II variation, one (1.51%) Type V, one (1.51%) Type III and 14 were Type IV. Three (4.55%) individuals had anatomical variations in disagreement; one (1.51%) classified as Type III in the MR cholangiography presented Type V in the intraoperative period, and the other two (3.02%) with Type IV variation in the MR cholangiography, one showed Type III and the other Type V in the

intraoperative findings.

Therefore, 44 (66.6%) donors presented findings in agreement, whereas 22 (33.3%) showed findings in disagreement.

In the statistical analysis, there was moderate agreement between the two methods (Kappa=0.46); in that sensitivity of MR cholangiography was 86%, specificity of 61%, positive predictive value of 49%, negative predictive value of 100% and accuracy of 70%.

Concerning the HA in all donors, the CT angiography results were in agreement with the intraoperative findings (100%) (Table 2).

TABLE 2 - Comparison of the anatomical variations of the hepatic artery

Anatomy type by Michels	Appearance	Results of CT	Results of intraoperative
1	Normal anatomy: proper hepatic artery divides into right and left hepatic arteries	68,2%	68,2%
2	Left hepatic artery replaced to left gastric artery	10,6%	10,6%
3	Right hepatic artery replaced to superior mesenteric artery	10,6%	10,6%
4	Both right and left hepatic arteries replaced to superior mesenteric artery and left gastric artery	0	0
5	Accessory left hepatic artery from left gastric artery	3,0%	3,0%
6	Accessory right hepatic artery from superior mesenteric artery	0	0
7	Accessory right and left hepatic arteries from superior mesenteric artery and left gastric artery	0	0
8	Replaced right hepatic artery and accessory left hepatic artery or replaced left hepatic artery with accessory right hepatic artery	0	0
9	Proper hepatic artery arising from superior mesenteric artery	3,0%	3,0%
10	Proper hepatic artery arising from left gastric artery	0	0
11	Others	4,5%	4,5%

Forty-five (68.2%) donors presented normal anatomy, that is, type I, seven (10.6%) type II, seven (10.6%) type III, two (3%) type V, and the remaining two showed type IX. In the last three donors (4.5%) the anatomy was type XI, and the variation observed did not fit in any type described. In sum, the common HA, branch of the celiac trunk, after passing the origin of the gastroduodenal artery continued as proper HA, then trifurcating into left HA and two right HA, and no anatomical variations of types IV, VI, VII, VIII and X were observed (Table 2).

The CT angiography reproduced the intraoperative findings of the HA (Kappa=1).

In regard to the PV, 46 (69.7%) donors presented Type I anatomy in agreement with the intraoperative findings, with anatomical variations in 15 (22.72%) in imaging examinations, and in 20 (30.3%) in the intraoperative period (Table 3).

TABLE 3 - Comparison of the anatomical variations of the portal vein

Anatomy type by Akgul et al	Appearance	Results of CT	Results of intraoperative
1	Normal anatomy: bifurcation of main portal vein and right portal vein	77,3%	69,7%
2	Trifurcation of main portal vein	10,6%	10,6%
4	Right anterior portal vein from left portal vein	10,6%	18,2%
8	Left portal vein from right anterior portal vein	1,5%	1,5%

In five (7.57%) cases showing Type I anatomy, variations were observed during surgery, two (3.03%) with Type II variations and three (4.54%) with Type IV. Thirteen (19.7%) donors had anatomical variations on CT that were confirmed in the intraoperative period. Among them, five (7.57%) were Type II, seven (10.6%) Type IV and one (1,51%) Type VIII. In the remaining two (3.03%) donors, the anatomical variations found were in disagreement with the surgical findings, classified as Type II in the preoperative period, while the intraoperative observation showed Type IV variation, with 59 donors (89.4%) presenting findings in agreement and only seven (10.6%) were in disagreement. In the statistical analysis, the Kappa coefficient was 0.75.

The sensitivity of CT was 87%, specificity of 90%, positive predictive value of 65%, negative predictive value of 100% and accuracy of 89%.

DISCUSSION

Liver transplant is an effective therapeutic modality for a variety of irreversible and end-stage hepatic diseases that are acute or chronic. Organ supply, since the first transplants till now, has been one of the limiting factors in survival of hepatic failure patients who are in the waiting list⁶.

2009, there were 4304 patients in the waiting list for liver transplant in Brazil. Organ donation has increased in the past years, achieving the ratio of 5.6 effective liver cadaver donors per million population in 2006, and rising to 6.4 in 2008 and 7.0 in 2009¹⁹. This is still a small number as compared to other countries, such as the United States, where the ratio is 24 per million population, and Spain, with 34 per million population, representing the highest ratio throughout the world²⁶.

The living-related liver transplant has many advantages in relation to cadaver donor liver transplant, leading to increased number of organs available, reduced time in the waiting list for recipient of cadaver organ, excellent feasibility of the donated hepatic segment due to less ischemia time of the graft and the possibility of performing the procedure in an elective manner⁷.

Priority in this type of intervention is given to donor's safety. Mancero *et al.* described a morbidity rate of 25%, and the most frequently observed complication

was biliary fistula, in 8.8% of donors, and one case of thrombosis of the PV¹⁹. In Japan, in 2003, the first death of a donor was described¹.

One of the crucial points for a safe procedure resides in previous knowledge of the hepatic anatomy. Bile duct complications are the most common in donors and recipients. In this sample, 46 (69.7%) donors had a normal biliary tree on the MR cholangiography and 20 (30.3%) donors showed anatomical anomalies. However, during the surgery, it was observed that 39 (59.1%) donors presented alterations. In three (4.5%) donors there was trifurcation of the common hepatic duct. In two (3%) donors the anterior or posterior right hepatic duct was connected to the common hepatic duct. In 27 (40.9%) donors anterior or posterior right hepatic duct was united to the left hepatic duct. In seven donors (10.6%) all sectoral ducts drained separately, with no defined confluence.

The biliary anatomical variations of this study had a different incidence as compared to previous literature reports. The anatomy of the confluence of the right and left bile ducts has diverse results. The pattern described as normal for the biliary tree, that is, with the anterior and posterior right sectoral ducts uniting to form the right hepatic duct, which, in turn, connects to the left hepatic duct forming the common hepatic duct, was described in 57% of patients by Couinaud⁹, in 67.7% by Yoshida *et al.*³⁰, and in 62.2% by Huang *et al.*¹³. In the present study the biliary tract considered normal was observed in only 40.9%.

Anatomical variation most often described is trifurcation of the common hepatic duct, identified in 19% by Huang *et al.*²⁷, and in 14.3% by Varotti *et al.*²⁷, and it was found in only 4.5% of our donors.

Another frequent variation is drainage of the right anterior or posterior duct directly into the left hepatic duct, described by Yoshida *et al.*³⁰ with an incidence of 8% for the posterior duct and 6% for the anterior duct; this modification was described in 24% of cases by Couinaud⁹ and in 20.8% by Varotti *et al.*²⁷. In this study this pattern of branch formation was the anatomical variation more frequently observed, present in 40.9% of donors, with no defined confluence in 10.9% of the individuals; such findings were higher than those described by Couinaud⁹ (3%) and by Yoshida *et al.*³⁰ (0.5%). In addition, in 3% of our donors the right anterior or posterior duct were connected to the common hepatic duct, and this incidence is slightly lower than that observed by Huang *et al.*¹³ (5%), Yoshida *et al.*³⁰ (8%) and Couinaud⁹ (6%).

The 66 donors submitted to CT angiography presented findings of HA in agreement; in other words, 100% sensitivity and 100% specificity.

In the present study, normal arterial anatomy was observed in 68.2% of the donors, and this result is similar to those of Michels²¹, in 55% of donors; in 60% according to Schoroeder *et al.*²⁴; 59% by Duran *et al.*¹¹; 70.8% by Varotti *et al.*²⁷ and in 75% by Freitas *et al.*

al.¹². In 10.6% of the donors the left HA originated from the left gastric artery, and this finding is in agreement with 10% by Michels²¹, 8% by Duran *et al.*¹¹. Results disagreeing from those were presented by Saylisoy *et al.*²³ in 4%, Tsang *et al.*²⁵ in 3% and Schoroeder *et al.*²⁴ in 4%. Another frequent variation presented was the right HA originating from the superior mesenteric artery, observed in 10.6% of our donors, and similar to 11% of Michels²¹, to those found by Saylisoy *et al.*²³ (10%), Schoroeder *et al.*²⁴ (8,4%), Duran *et al.*¹¹ (10%) and Freitas *et al.*¹² (9%). Artioli *et al.*³ reported a higher incidence of this variation (15.6%), but Tsang *et al.*²⁵ described a lower incidence of 5.7% and Coskun *et al.*⁸ of 6.3%. An accessory left HA, a branch of the left gastric artery, was observed in 3% of our donors. This modification was found in 7%²¹, 16.6%⁸, 16%²⁴, 9.8%²⁵ and in 4%²³ by other researchers. In 3% of the donors, the common HA originated from the superior mesenteric artery, a finding similar to that of 2.5% found by Michels²¹ and 4%, according to Duran *et al.*¹¹, but slightly inferior to that of Saylisoy *et al.*²³ who reported type of variation in 6%, and slightly higher than the 1.6% described by Schodoeder *et al.*²⁴. A total of 4.5% of donors could not be classified since the common HA, a branch of the celiac trunk, after originating the gastroduodenal artery continued as proper HA and trifurcated, forming one left HA and two right HA. Several authors reported alterations that had not been described by Michels⁵, including Freitas *et al.*¹³ with 13.6%, Coskun *et al.*⁸ with 16.6%, Duran *et al.*¹¹ with 11% and in 2.2% of the donors according to Tsang *et al.*¹³.

Based on the CT angiography findings, in 51 (77.3%) donors the anatomy of the PV was normal and 15 (22.7%) presented variations. In seven (10.6%) the main PV was formed by the confluence of the left branch and the anterior and posterior right PV, leading to trifurcation. In another seven (10.6%) donors, the posterior right branch drained directly into the main PV, whereas the right anterior vein to the left PV and from this to the main vein. In one (1.5%) donor the main PV was formed by the confluence of the posterior and anterior branches of the right PV, and the left portal vein drained into the anterior branch of the right PV.

During the surgical procedure, anatomical variations of the PV were observed in 20 (30.3%) donors. The anomalies found were as follows: seven (10.6%) with trifurcation of the main PV; in 12 (18.2%) the right posterior branch drained directly in the main PV, while the anterior right vein to the left PV, which drained to the main PV. In one (1.5%) donor the main portal vein was formed by the confluence of the posterior and anterior branches of the right PV, and the left PV drained to the anterior branch of the right PV. Such variations are described by Tsang *et al.*²⁵ in 14.7% of the cases, whereas Covey *et al.*¹⁰ reported 35%, Macdonald *et al.*¹⁸ found 18% and Schoroeder *et al.*²⁴, Saylisoy *et al.*²³ 12%, Koç *et al.*¹⁵ 21.5% with anatomical variations. Artioli *et al.*³ reported in just 9% of donors.

In sum, MR cholangiography presented moderate accuracy of 70%, with agreement in 66.6% of the cases as compared to intraoperative colangiography; the CT showed 100% of agreement in assessing the arterial anatomy of the donors, high accuracy (89%) in identification of anatomical variations of the PV and reproduced the surgical findings in 89.4% of the cases.

CONCLUSION

The imaging methods are reliable to evaluate the anatomical anomalies of the portal vein and of the hepatic artery, but a more refined technique is required for the biliary tract.

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