Angiographic Evaluation of Hepatic Artery Variations in 405 cases

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The purpose of this study is to evaluate the angiographic variations of hepatic arteries and to compare with the previous reports in literature in large series.

Records of 405 patients who underwent upper abdominal arteriography between Aug. 1998 and Sep. 2004 were reviewed. Hepatic artery anatomy was analyzed and classified according to Suzuki’s classification. Single hepatic artery group included 283 of 405 cases (69.9 per cent). Double hepatic artery group included 114 cases (28.1 per cent). Multiple hepatic artery group included 8 cases (2.0 per cent). Seventeen patterns were identified in this study.

The complex vascular anatomy of the liver and the high incidence of normal vascular variants reinforce the need for accurate preoperative vascular imaging. This study is useful for planning surgical and radiological procedures of the upper abdomen and preventing some of the serious accidents.

Key words: Angiography; Hepatic arteries; Normal variant

Thorough knowledge of vascular anatomy with variable variants is basic and very important to every radiologist and surgeon. The extrahepatic arteries must be identified with precision at the time of liver harvest to avoid injuries that might compromise complete artery ligation of the graft [1]. It is also important as a guide to operation in the stomach, pancreas, or gall-bladder. Vascular variations can also become a technical problem for infusion therapy and transarterial chemoembolization of neoplasm in the liver [2-4].

In 1966, Michels described his classification scheme for anatomic variations in the hepatic arterial blood supply based on the results of dissecting 200 cadavers [5]. This classification was modified by Hiatt in 1994 [1]. Suzuki presented a new classification based on the hepatic arterial pattern at the hilar region in 1971 [6]. Several studies on hepatic arterial angiographic anatomy have been reported in Taiwan [2, 7, 8]. We review the findings of 405 selective angiograms of population at Eastern Taiwan and compare them with those obtained in other large series.

MATERIALS AND METHODS

From Aug. 1998 to Sep. 2004, selective upper abdominal arteriography was performed in our department on 462 patients. Of these cases, 57 cases were excluded from this study because of insufficient or improper opacification of the hepatic arteries, prominent tumor vessels obliterating the normal hepatic arterial architecture, or huge hepatic neoplasms distorting the normal course of the hepatic arteries. Duplicate data on individual patients, such as those who were undergoing repeat embolization and patients who previously had undergone hepatic resection were also excluded. There were 405 cases (290 males and 115 females) selected for this study, ranging in age from 3 to 96 years old (Mean ± SD, 62.3 ± 13.59). The indication for angiography was hepatic arterial embolization in 172, preoperative planning in 128, gastrointestinal bleeding in 72, ischemic bowel disease

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in 23, splenic artery embolization in 4, hepatic artery infusion chemotherapy in 3, and transjugular intrahepatic portosystemic shunt (TIPS) in 3.

The percutaneous catheterization of the femoral artery was performed using the standard Seldinger technique. Celiac and superior mesenteric artery (SMA) angiographies were performed routinely: 25-40 ml of contrast medium was administered at a rate of about 3-5 ml/sec. Selective hepatic or left gastric angiography (2 ml/sec for 4-5 sec) was performed to define the intrahepatic arteries. Digital subtraction angiograms were acquired on an Advantx LCA angiography system (General Electric Medical Systems, Milwaukee, WI). Two experienced interventional radiologists retrospectively analyzed these 405 angiograms.

We reviewed the angiographic findings of 405 patients according to the Suzuki’s classification[6]. The numbers of the hepatic arteries constitute the primary factor in classifying variations of the artery. These are classified into three groups. Group I had one hepatic artery (proper hepatic artery), group II had two independent hepatic arteries, and group III had three or more hepatic arteries entering the liver at the hilar region. Each group is divided into three types in correspondence with the arteries from which the hepatic artery originates. The celiac type is defined as the hepatic artery deriving from the celiac trunk or its branches. The mesenteric type is the hepatic artery arising from the SMA or its branches. The mixed type is the hepatic artery coming from both celiac and superior mesenteric arteries, or very rarely, from celiac and abdominal aorta. These types are subdivided into various patterns according to the course of the artery.

**RESULTS**

Incidence and the number of patterns of each group are shown in Table 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Current series (%)</th>
<th>Koops et al (%)</th>
<th>Chen et al (%)</th>
<th>Li and Kawanishi (%)</th>
<th>Suzuki et al (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (Single hepatic artery group)</td>
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<td></td>
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<td></td>
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<tr>
<td>A. Celiac type (1 pattern)</td>
<td>65.5</td>
<td>79.5</td>
<td>67.5</td>
<td>66.7</td>
<td>55.0</td>
</tr>
<tr>
<td>B. Mesenteric type (2 patterns)</td>
<td>4.4</td>
<td>2.8</td>
<td>1.0</td>
<td>5.1</td>
<td>3.5</td>
</tr>
<tr>
<td>Group 2 (Double hepatic artery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Celiac type (5 patterns)</td>
<td>22.9</td>
<td>4.3</td>
<td>19.7</td>
<td>12.8</td>
<td>28.0</td>
</tr>
<tr>
<td>1. Same artery origin</td>
<td>15.5</td>
<td>0.2</td>
<td>12.9</td>
<td>0.6</td>
<td>15.5</td>
</tr>
<tr>
<td>2. Different artery origin</td>
<td>7.4</td>
<td>4.1</td>
<td>6.8</td>
<td>12.2</td>
<td>12.5</td>
</tr>
<tr>
<td>B. Mixed type (5 patterns)</td>
<td>5.2</td>
<td>13.3</td>
<td>7.1</td>
<td>10.3</td>
<td>8.0</td>
</tr>
<tr>
<td>C. Mesenteric type</td>
<td>0</td>
<td>0</td>
<td>0.8</td>
<td>1.3</td>
<td>1.0</td>
</tr>
<tr>
<td>Group 3 (Multiple hepatic artery)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. Celiac type (1 pattern)</td>
<td>0.8</td>
<td>0</td>
<td>2.6</td>
<td>1.3</td>
<td>0.5</td>
</tr>
<tr>
<td>B. Mixed type (3 patterns)</td>
<td>1.2</td>
<td>0.3</td>
<td>1.3</td>
<td>2.6</td>
<td>4.0</td>
</tr>
<tr>
<td>C. Mesenteric type</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 1. Group 1 (single hepatic artery). Schematic illustration of each pattern and its incidence. The thick line shows the hepatic artery; □ = celiac trunk; ● = superior mesenteric artery; CH = common hepatic artery; SP = splenic artery; PH = proper hepatic artery; GD = gastroduodenal artery; RH = right hepatic artery; LH = left hepatic artery; LG = left gastric artery.

Group 1 (single hepatic artery) included 283 of 405 cases (69.9 per cent); 265 were of the celiac type and 18 of the mesenteric type. Different patterns of the hepatic artery in this group were illustrated in Figure 1. The celiac type consisted of one pattern and the mesenteric type of two patterns.

Group 2 (double hepatic artery) included 114 cases (28.1 per cent); 93 were of the celiac type and 21 of the mixed type. The celiac and mixed type consisted of five patterns each and no mesenteric type was noted. Different patterns of the hepatic artery in this group were illustrated in Figure 2.
Table 2. Incidence of hepatic arterial type according to Hiatt’s classification (%)

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>I</td>
<td>65.4</td>
<td>67.5</td>
<td>79.1</td>
<td>55.0</td>
<td>75.7</td>
</tr>
<tr>
<td>II</td>
<td>6.2</td>
<td>6.6</td>
<td>3.0</td>
<td>12.5</td>
<td>9.7</td>
</tr>
<tr>
<td>III</td>
<td>4.0</td>
<td>6.6</td>
<td>11.9</td>
<td>7.5</td>
<td>10.6</td>
</tr>
<tr>
<td>IV</td>
<td>0.5</td>
<td>1.0</td>
<td>1.3</td>
<td>4.5</td>
<td>2.3</td>
</tr>
<tr>
<td>V</td>
<td>3.2</td>
<td>0.5</td>
<td>2.8</td>
<td>3.0</td>
<td>1.5</td>
</tr>
<tr>
<td>VI</td>
<td>0.5</td>
<td>0.0</td>
<td>0.2</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Others</td>
<td>20.2</td>
<td>17.8</td>
<td>1.7</td>
<td>17.5</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Figure 2. Group 2 (double hepatic artery). Schematic illustration of each pattern and its incidence. The thick line shows the hepatic artery.
Group 3 (multiple hepatic artery) included 8 cases (2.0 per cent); 3 were of the celiac type and 5 of the mixed type. The mixed type consisted of 3 patterns. No mesenteric type was found in this group. Different patterns of the hepatic artery in this group were illustrated in Figure 3.

Some patterns reported by Suzuki and Chen were not identified in this study.

**DISCUSSION**

Michels' classic autopsy series of 200 dissections, published in 1966, defined the 10 basic anatomic variations in hepatic arterial supply have served as the benchmark for all subsequent contributions in this area [5]. This classification was modified to 6 types by Hiatt in 1994 [1]. Hiatt's modified and simplified classification has been applied in many subsequent series, as shown in Table 2, which includes three angiographic studies and one study on transplantation grafts.

The so-called classic pattern and branches of the hepatic artery (Michels’ type I, Hiatt’s type I) was reported in 50 - 75% of patients on the basis of cadaver and early angiographic reports [5, 6, 9-11]. However, 20.2% of our patients could not be classified by Michels’ or Hiatt’s system. In 1971, Suzuki et al contributed an article on the surgical importance of anatomic variants of the hepatic arteries that was based on findings in 200 patients examined with cut-film angiography [6]. It emphasized the detailed hepatic arterial variation at the hepatic hilum. We applied the classification in our study.

In comparison with Hiatt’s study, our study had a lower incidence (69.9%) of textbook pattern (Hiatt’s type I) arteries, but higher than Suzuki’s study. The

![Figure 3](image)

**Figure 3.** Group 3 (multiple hepatic artery). Schematic illustration of each pattern and its incidence. The thick line shows the hepatic artery; MH = middle hepatic artery.

![Figure 4](image)

**Figure 4.** Double hepatic artery type. **a.** Left hepatic artery (arrowheads) arises from common hepatic artery, classified as variant of classic type by Hiatt’s classification. **b.** Trifurcation of common hepatic artery into RHA, LHA and GDA (arrowhead) with no proper hepatic artery, which is classified as variant of classic type by Hiatt’s classification.
major difference between Hiatt's and Suzuki's classification is the so-called double hepatic artery. In Hiatt's classification, double hepatic artery is thought to be a variant of textbook pattern (Hiatt's type I). It is not uncommon but may be an important variant.

Double hepatic artery, including trifurcation of the common hepatic artery into the gastroduodenal artery, right and left hepatic artery, does have important surgical relevance, particularly for patients who are having pumps placed for hepatic arterial infusion of chemotherapeutic agents (Fig. 4).

The incidence of our single hepatic artery type, mesentery pattern is higher than other series in Taiwan. The difference could be due to races. It is of surgical importance during the upper abdomen operation (Fig. 5, 6). It is also important in planning liver transplantation, hepatic artery infusion (HAI) chemotherapy and transarterial chemoembolization. The preoperative visceral angiogram provides a map for devascularization. The presence of an aberrant vessel can result in incomplete embolization of liver tumors and improper catheter tip placement, causing damage to normal liver parenchyma during chemoembolization or HAI chemotherapy.

The developments of CT angiography (CTA) and gadolinium-enhanced magnetic resonance angiography (MRA) provide non-invasive imaging modalities for the evaluation of three-dimensional relationships of vessels around the liver hilum [12-16]. But these are limited for preoperative evaluation of hepatic arterial variation in arteries of small diameter. They cannot substitute for conventional angiography in every case. If there is a missing artery or equivocal arterial anatomy on CTA or MRA, conventional angiography is mandatory [17].

In conclusion, knowledge of the hepatic arterial variations is important for interventions in abdominal viscera. This study is useful for planning surgical and radiological procedures in the upper abdomen and can help preventing some of the serious accidents or providing favorable therapeutic outcomes.

REFERENCES
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405例血管攝影評估肝動脈變異

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本研究的目的在於以血管攝影評估肝動脈的變異性，並比較與其他研究的不同。回顧在1998年8月至2004年9月間405位病人的上腹部血管攝影影像，以鈴木（Suzuki）分類法分析肝動脈的變異性。單一肝動脈在405位病中人有283位（69.9%），雙重肝動脈有114位（28.1%），多重肝動脈有8位（2.0%）。本研究中共找到17種變異型。由於肝臟周圍的血管走向複雜且變異性大，術前明確的血管影像是必要的。本研究可幫助上腹部手術或是介入性放射治療的術前評估，避免嚴重的併發症發生。

關鍵詞：血管攝影；肝動脈；正常變異