Embolisation of the right gastric artery in patients undergoing hepatic arterial infusion chemotherapy using two possible approach routes

T YAMAGAMI, MD, PhD, K TERAYAMA, MD, PhD, R YOSHIMATSU, MD, T MATSUMOTO, MD, H MIURA, MD and T NISHIMURA, MD, PhD

Department of Radiology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajii-chyo, Kawaramachi-Hirokoji, Kamigyo, Kyoto 602-8566, Japan

ABSTRACT. We used a retrospective non-randomised study to investigate the clinical effect of selective embolisation of the right gastric artery before hepatic arterial infusion chemotherapy (HAIC) using a port-catheter system. We evaluated whether the hepatic artery or the left gastric artery is the better approach for selecting the right gastric artery. A total of 367 patients (244 men and 123 women; mean age, 64.1 years) with unresectable advanced liver cancer underwent percutaneous implantation of a port-catheter system. In 294 of these patients, right gastric arterial embolisation with microcoils was attempted before placement of the port-catheter system to prevent gastric mucosal lesions. Approach was either through the hepatic artery (175 patients) or through the left gastric artery (119 patients), with success rates in catheterising the right gastric artery of 78.3% and 77.3%, respectively. If the attempt was unsuccessful, the catheter was redirected to the alternative approach, which increased the final success rate to 96.3%. Only seven patients experienced gastroduodenal mucosal lesions acutely after HAIC, as revealed by endoscopy. Embolisation of the right gastric artery is a feasible procedure that can reduce the incidence of gastric mucosal lesions associated with HAIC. Approach through either the hepatic artery or the left gastric artery is equally acceptable.

Received 24 February 2009
Revised 15 April 2009
Accepted 9 June 2009

DOI: 10.1259/bjr/51736762

© 2010 The British Institute of
Radiology

Long-term hepatic arterial infusion chemotherapy (HAIC) via an implanted port-catheter system is a treatment option for patients with unresectable advanced liver cancer [1, 2]. In the past, such catheter placement was done by surgical laparotomy under general anaesthesia [3–6], an invasive procedure. However, recent advances in interventional techniques allow the implantation of port-catheter systems percutaneously under local anaesthesia [7–14].

A frequent complication is reactive gastric or duodenal mucosal lesions, which result from chemical irritation caused by infusion of chemotherapeutic agents into adjacent organs through arteries originating from the common hepatic artery [15–24]. One such complication is a gastric mucosal lesion caused by inflow of chemotherapeutic agents into the right gastric artery [15–24]. To prevent this complication, the efficacy of selectively embolising the right gastric artery with coils at the time of implantation of the port-catheter system has been noted [21, 25–27].

In many cases, however, the right gastric artery is slender and angulated, with anatomical variations [26, 28–31]. Hence, it is occasionally difficult to insert a catheter selectively into the right gastric artery by

antegrade catheterisation via the site of the hepatic artery. This is the approach most commonly used by interventional radiologists. Failure to embolise the right gastric artery can result [26]. As an alternative method, a retrograde approach to the right gastric artery via the left gastric artery has been introduced [32, 33].

Because HAIC with an implanted port-catheter system is performed in a relatively large number of cases in our institution, we have many opportunities to embolise the right gastric artery using both approaches. The aim of the present retrospective non-randomised study, which included a large number of subjects, was to evaluate the usefulness of right gastric arterial embolisation and to determine whether the antegrade or retrograde approach is more useful.

Methods and Materials

Patients

Between October 1998 and September 2008, 367 patients (244 men and 123 women; mean age, 64.1 years; range, 23–87 years) with unresectable advanced liver cancer underwent successful placement of a percutaneously implantable port-catheter system for repeated HAIC at our institution. Of the 367 patients, 154 had primary liver cancer and 213 had metastatic liver cancer that originated from colorectal ($n=108$), breast ($n=36$),

Address correspondence to: Takuji Yamagami, Department of Radiology, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, 465 Kajii-chyo, Kawaramachi-Hirokoji, Kamigyo, Kyoto 602-8566, Japan. E-mail: yamagami@koto.kpu-m.ac.jp

gastric ($n = 29$), pancreatic ($n = 18$), gallbladder ($n = 11$), lung ($n = 3$), oesophageal ($n = 2$), duodenal ($n = 1$), eye ($n = 1$), ovarian ($n = 1$), uterine ($n = 1$), anal ($n = 1$) or jejunal cancer ($n = 1$). All of the patients had diffuse or multiple (more than five) malignant lesions or a few huge malignant lesions in both the right and left lobes of the liver.

Embolisation of the right gastric artery to prevent infusion of chemotherapeutic agents into the stomach was attempted in 306 of the 367 patients. The remaining 61 patients did not require embolisation of the right gastric artery because that artery had been ligated previously, for example during gastrectomy. In general, the right gastric artery was embolised on the day before port-catheter implantation. When it was necessary to start HAIC early for various reasons, embolisation of the right gastric artery was done as the first step in port-catheter implantation.

In patients who had more than two hepatic arteries, special preparation was necessary to allow perfusion of the entire liver from one catheter. All of the hepatic arteries were embolised with microcoils except the hepatic artery into which the indwelling catheter would be inserted, thereby converting multiple hepatic arteries into one. Details of this technique have been described elsewhere [34, 35].

Procedures

All procedures were performed by one of five experienced interventional radiologists in our institution after written informed consent was obtained from each patient.

Port-catheter implantation

Catheter placement procedures were performed with the patient under local anaesthesia. The indwelling catheter was inserted from the left subclavian artery ($n = 269$), from the femoral artery ($n = 35$) or from the hypogastric artery ($n = 2$).

The port-catheter system was implanted using either the fixed catheter tip technique [7, 8, 34] or the long tapered catheter placement technique [34, 36]. When the fixed catheter tip technique was used, the arterial branches used for fixing the catheter tip were the gastroduodenal artery ($n = 259$), the splenic artery ($n = 6$) or the left gastric artery ($n = 3$).

When the long tapered catheter placement technique was used, the catheter tip was inserted into the peripheral branch of the hepatic artery ($n = 38$). A side hole, through which HAIC was administered, was created to open at the hepatic artery. The proximal end of the indwelling catheter was connected to a port implanted in the subcutaneous space. Details of methods for port-catheter placement are described elsewhere [7, 8, 34, 36]. Follow-up arteriography, which was obtained while contrast agents were infused manually through the port, was performed every one to five months after port-catheter placement.

Right gastric arterial embolisation

Embolisation of the right gastric artery was performed using one of two routes: antegradely via the hepatic

artery (Figure 1) or retrogradely via the left gastric artery (Figure 2). With the antegrade route via the hepatic artery, the right gastric artery was embolised with microcoils introduced through a microcatheter (Renegade-18; Boston Scientific, Watertown, MA), which was coaxially advanced through the common or proper hepatic artery from a inserted 5-French catheter positioned in the coliac or common hepatic artery. For the retrograde route through the left gastric artery, embolisation of the right gastric artery was performed through a microcatheter coaxially advanced via the left gastric artery, which was inserted from a 5-French catheter positioned in the coliac axis or at the origin of the left gastric artery. Before embolisation, celiac arteriography was performed in all patients to delineate the precise anatomy. The microcoils were Diamond Coil (Boston Scientific, Watertown, MA; Trufill, Cordis, Miami, FL); C-stopper (Solution, Tokyo, Japan); or Tornado or Micronester Coil (Cook, Bjæverskov, Denmark). When hepatofugal blood flow in the right gastric artery continued to be present on arteriography, even after embolisation of the right gastric artery with microcoils alone, *n*-butyl cyanoacrylate (NBCA) mixed with Lipiodol (Laboratoire Guerbet, Roissy, France) was added as an embolic agent through the microcatheter used for insertion of the microcoils. The ratio of NBCA to Lipiodol was 1:1–1.5.

When the course of the gastric artery was too tortuous for the microcatheter to be advanced easily, the patient swallowed effervescent granules (Baros; Horii, Osaka, Japan) to assist advancement of the microcatheter because the stomach was stretched by gaseous distension, thereby straightening the course of the gastric artery.

Before April 2000, the antegrade approach via the hepatic artery was selected as the initial approach route in all cases. Between May 2000 and July 2001, the retrograde approach via the left gastric artery was chosen as the initial approach route in all patients. After August 2001, the initial approach route was decided on the basis of the initial angiographic images.

Parameters investigated

The rate of success in embolisation of the right gastric artery was compared between the two approaches: that via the common or proper hepatic artery and that via the left gastric artery. We also investigated management of the right gastric artery when embolisation by the first approach failed, and complications related to this procedure. Data were retrospectively collected by reviewing charts and the recorded results of imaging studies.

Results

As shown in Table 1, the position at which the port-catheter system was implanted was determined by the location of the catheter tip and the side hole, and by other factors that became evident at the time of implantation. The procedures used for port-catheter implantation can be broadly classified into seven categories: for categories 1–3 and 7, implantation was by the fixed catheter tip

Figure 1. Hepatocellular carcinoma in a 69-year-old man. (a) Common hepatic arteriography before implantation of port-catheter system shows that the right gastric artery arises from the proper hepatic artery (arrow). (b) Arteriography obtained using a microcatheter (small arrow), which is coaxially advanced from a 5-French catheter placed in the hepatic artery (arrowhead), shows the right gastric artery communicating with the left gastric artery. A microcoil can be seen in the falciform artery (large arrow). (c) Common hepatic arteriography obtained after embolisation of the right gastric artery with three microcoils shows remnant hepatofugal flow in the right gastric artery (arrow). (d) Roentgenogram obtained after insertion of *n*-butyl cyanoacrylate mixed with Lipiodol through the microcatheter inserted into the right gastric artery. This treatment is sufficient to embolise the right gastric artery, and a cast of *n*-butyl cyanoacrylate is distributed extensively (arrows).

technique; for categories 4–6, the long tapered catheter placement technique was used.

Angiographic examinations revealed that, among the 306 study patients, the origins of the right gastric artery were the proper hepatic artery ($n = 171$, 55.9%), the common hepatic artery ($n = 31$, 10.1%), the left hepatic artery ($n = 59$, 19.3%), the right hepatic artery ($n = 10$, 3.3%), the middle hepatic artery ($n = 10$, 3.3%) or the gastroduodenal artery ($n = 21$, 6.9%). In four patients

(1.3%), the right gastric artery was not detected by either common hepatic arteriography or left gastric arteriography. Embolisation of the right gastric artery was not performed in 12 of the 306 patients because the procedure was considered to be unnecessary or impossible for various reasons. In three patients, the right gastric artery arose from the gastroduodenal artery and the distance from the bifurcation was so great that only embolisation of the gastroduodenal

Figure 2. Arteriographs from a 56-year-old woman who has liver metastasis of breast cancer. (a) Coeliac arteriography before implantation of the port-catheter system shows the replaced right hepatic artery arising from the common hepatic artery (arrow). Note that the right gastric artery is not detected. (b) Arteriography obtained using a microcatheter (arrows), which is coaxially advanced into the left gastric artery from a 5-French catheter placed in the coeliac artery (arrowhead), shows communication between the left and right gastric artery. (c) Arteriography obtained after a microcatheter was advanced into the right gastric artery shows the right gastric artery arising from the left hepatic artery (arrow). (d) Arteriography obtained using a microcatheter shows that the right gastric artery is embolised (arrow). (e) Arteriography by way of the port obtained just after implanting a port-catheter system shows that the indwelling port-catheter system is correctly implanted percutaneously. All of the hepatic arterial branches are shown. The distal tip of the catheter is fixed to the gastroduodenal artery with five microcoils (large arrow). Note that the microcoils are inserted into the replaced right hepatic artery that arose from the common hepatic artery to convert two hepatic arteries into one (arrowhead), and that the right gastric artery is embolised with two micro-coils (small arrow).

artery at the time of catheter tip fixation was considered to be sufficient to stop blood flow into the gastric artery. In five cases, the side hole of the indwelling catheter opened into the hepatic site from the point arising from the right gastric artery; thus, it was considered that the drug infused from the indwelling catheter might not distribute into the right gastric artery. In the remaining four patients, no right gastric artery was evident arteriographically.

In 229 (77.9%) of the 294 patients, the right gastric artery was successfully embolised by the first attempt. A subsequent attempt resulted in successful embolisation in an additional 54 patients, with a final success rate of

96.3% (283/294). In seven of those 283 patients, gaseous distension of the stomach by the use of effervescent granules was required to advance the microcatheter and accomplish embolisation.

In 137 of the 175 (78.3%) patients in whom the microcatheter was advanced through the site of the hepatic artery, the right gastric artery was successfully catheterised by the first approach. In 31 of the remaining 38 patients, the route for advancement of the microcatheter was changed to the left gastric artery during the same procedure. Embolisation of the right gastric artery was successfully accomplished in 28, with failure resulting in the other three patients.

Table 1. Procedures performed to implant a port-catheter system percutaneously for hepatic arterial infusion chemotherapy

Category no.	Location of catheter tip	Catheter tip fixation with embolic agents	Location of side hole opening	Arteries requiring occlusion to prevent anticancer drugs from distributing to adjacent organs other than the right gastric artery	No. of cases performed
1	GDA	Present	CHA	GDA, PDA	256
2	GDA	Absent	CHA		3 ^a
3	SpA	Present	CA	LGA, GDA, PDA	6
4	Peripheral branch of HA	Absent	PHA		1
5	Peripheral branch of HA	Absent	CHA	GDA, PDA	33
6	Peripheral branch of HA	Absent	Right HA		4 ^b
7	LGA	Present	CA		3 ^c

CA, coeliac artery; CHA, common hepatic artery; GDA, gastroduodenal artery; HA, hepatic artery; LGA, left gastric artery; PDA, branch of pancreaticoduodenal arcade; PHA, proper hepatic artery; SpA, splenic artery.

^aCase in which hepatopetal flow through the gastroduodenal artery was strong.

^bCase with two hepatic arteries converted into the right hepatic artery arising from the superior mesenteric artery.

^cCase with unresectable primary pancreatic cancer with liver metastasis.

Of the 119 patients in whom the microcatheter was advanced via the left gastric artery, the right gastric artery was successfully catheterised using the first approach in 92 (77.3%). There was no communication between the right and left gastric artery in 3 of the 27 patients in whom catheterisation by this route failed. In 26 of those 27 patients, however, embolisation was successfully achieved after changing the approach route to that from the hepatic artery during the same procedure.

In summary, the success rate of first attempts to advance a microcatheter selectively into the right gastric artery did not differ significantly between the approach from the hepatic artery and that from the left gastric artery (137/175 versus 92/119, respectively, $p = 0.8434$ on χ^2 test). The approach route that was successful in embolisation of the right gastric artery was the antegrade route through the hepatic artery in 163 patients and the retrograde route through the left gastric artery in 120 patients.

The mean number of microcoils used among all patients in whom embolisation was accomplished was 2.3 ± 1.2 (mean $\pm$ standard deviation; range, 0–7). When the microcatheter was inserted via the hepatic artery, the mean number of microcoils used was 2.4 ± 1.3 (mean $\pm$ standard deviation; range, 0–7); for approach via the left gastric artery this number was 2.1 ± 1.0 (mean $\pm$ standard deviation; range, 1–7) ($p = 0.0242$, unpaired t -test). *n*-Butyl cyanoacrylate mixed with Lipiodol was used as an additional embolic agent in four patients in whom the right gastric artery was embolised antegradely via the hepatic artery but in only one patient who underwent an approach from the left gastric artery (4/163 versus 1/120, $p = 0.3995$ by Fisher's exact probability method). Coincidentally, the operator using NBCA was the same for all five patients.

The complications directly related to embolisation of the right gastric artery are summarised in Table 2 and did not differ significantly according to the approach route. In six of eight cases in which misplacement of a coil into the hepatic artery occurred, the coil was successfully retrieved with the Microsnare kit (Amplatz Goose Neck Microsnare Kit; Microvena, White Bear Lake, MN). After retrieval of the misplaced microcoil, new microcoils were correctly placed into the right gastric artery. In the remaining two patients, we failed to retrieve the misplaced coil, but all hepatic arteries were visualised on hepatic arteriography through intrahepatic collateral vessels. Subsequently, other microcoils were correctly placed into the right gastric artery in both cases. In seven patients, recanalisation of the right gastric artery was recognised on arteriography via the port performed for follow-up. The mean period between embolisation and recanalisation being noticed was 36.6 ± 31.0 days (mean $\pm$ standard deviation; range, 5–88 days). In six of these seven cases, the right gastric artery was re-embolised, while in the remaining patient re-embolisation was not performed but careful observation revealed no problems. In one patient, gastrointestinal symptoms developed after embolisation but before starting HAIC, and the presence of a gastromucosal lesion was confirmed endoscopically. The procedures used for this patient are shown in Figure 1. HAIC was started after the gastric mucosal lesion was cured with antiulcerative drugs. In this patient, *n*-butyl cyanoacrylate had been used in addition to three microcoils for embolisation of the right gastric artery.

Gastrointestinal symptoms developed acutely after HAIC in 7 (2.3%) of the entire group of 306 patients. Five patients had gastromucosal lesions and two had duodenal mucosal lesions, as revealed by endoscopy. Of

Table 2. Complications or difficulties related to embolisation of right gastric artery according to final approach route

Complications or difficulties	Final approach route		<i>p</i> -value ^b
	Hepatic artery (<i>n</i> = 163)	Left gastric artery (<i>n</i> = 120)	
Migration of coils into hepatic artery	4	4	0.7259
Recanalisation of once embolised right gastric artery	3	4	0.4622
Gastric mucosal lesions ^a	1	0	>0.9999

^aNot due to hepatic arterial infusion chemotherapy.

^bAccording to Fisher's exact probability method.

the 5 patients with gastromucosal lesions, 3 were among the 11 patients (27.3%) in whom embolisation of the right gastric artery could not be accomplished. Among those three cases, HAIC had to be abandoned in two because of severe gastromucosal lesions but, in one, embolisation of the right gastroartery, which was not achieved at the first attempt, was successfully performed and HAIC was resumed. In the remaining two of those five patients, both gastric ulcer and gastritis occurred. Arteriography performed while contrast material was infused through the port revealed recanalisation of the right gastric artery in one of these patients; in the other patient, the right gastric artery remained embolised. In both cases, chemotherapy via the port-catheter system was withdrawn once and the gastromucosal lesions were treated. In addition, in the patient whose right gastric artery was recanalised, embolisation was performed again and, after an interval, intra-arterial infusion chemotherapy was resumed. In both of the patients who had duodenal mucosal lesions, new development and/or recanalisation of branches of the pancreaticoduodenal arcade were shown on arteriography via the port. All of these branches were subsequently embolised, resulting in resumption of HAIC.

Discussion

Gastromucosal lesions, which have been reported to occur in 3.2–47.5% of patients who have undergone repeated administration of HAIC [15–21], are caused by opening of the right gastric artery through which chemotherapeutic agents are distributed to the wall of the stomach. Embolisation of the right gastric artery has been proposed as a means of avoiding this drug-induced complication [7, 21, 27]. In a review of 217 patients who underwent repeated HAIC, Inaba et al [27] reported that only 2.6% of 192 patients in whom the right gastric artery was sufficiently embolised before percutaneous port-catheter placement developed gastromucosal lesions, whereas 36.0% of 25 patients without sufficient embolisation developed such lesions. This difference was statistically significant. In the present study, definite gastroduodenal mucosal lesions caused by HAIC developed in only four (1.4%) of 283 patients who had successful gastric arterial embolisation.

The right gastric artery is usually small (less than 2 mm in diameter), angulated and rich in anatomical variations [21]. Hence, it is sometimes difficult to advance catheters selectively from the site of the hepatic artery into the right gastric artery. As regards anatomical variations, the most common reported sites of divergence of the right gastric artery are the proper hepatic artery (in 40–52% of individuals) [21, 26, 30, 31] and the right or left hepatic artery (in 21–42%) [21, 26, 30, 31]. Divergence also has been reported in the common hepatic artery (in 1.5–10%) [6, 30, 31] and the gastroduodenal artery (in 1.5–2.7%) [26, 31]. These frequencies of sites of divergence are similar to those seen in the present study, suggesting that our subjects did not differ appreciably from those of other cohorts.

As is well known, the right gastric artery generally anastomoses with the left gastric artery [29]. This led us to speculate that advancing the microcatheter to the right

gastric artery through the left gastric artery would be possible, even though the hepatic artery was usually used for this purpose. Hashimoto et al [32] were the first to report attempted catheterisation of the right gastric artery through the left gastric artery. They succeeded in selective catheterisation of the right gastric artery using this route in 12 of 14 (86%) patients with smooth anastomoses between the right and left gastric artery. In a later report of embolisation of the right gastric artery using the retrograde approach, embolisation was successful in 79 (89.8%) of 88 patients [33].

Even though the success rate of the first approach for embolisation of the right gastric artery was not low (77.9%), whichever approach was used first, subsequent use of the alternative approach gave a very high eventual success rate of 96.3%. No serious complications occurred other than a gastromucosal lesion that developed after embolisation in one patient. All other complications such as misplacement of coils and recanalisation, all of which could be amended, were not serious. There was no significant difference in the rate of these complications between the antegrade and retrograde approaches, neither did the success rate differ between approaches. Only the number of coils used to embolise the right gastric artery differed significantly between the two approaches; however, the number of coils used was very small with either approach (mean: 2.4, hepatic artery; 2.1, left gastric artery).

Undoubtedly, the approach to the right gastric artery antegradely from the hepatic artery is more widely known and therefore performed more often than the lesser-known approach via the left gastric artery. However, the conclusion that can be drawn from the satisfactory results of both previous studies [26, 33] and the present study is that advancement of microcatheters via the left gastric artery into the right gastric artery is a useful and safe method. This route may be used as an alternative approach when the usual route via the site of the hepatic artery fails. A limitation is that this route cannot be used when the anastomosis between the right and left gastric arteries is too small to allow the microcatheter to advance or is non-existent.

References

1. Lorenz M, Muller HH. Randomized, multicenter trial of fluorouracil plus leucovorin administered either via hepatic arterial or intravenous infusion versus fluorodeoxyuridine administered via hepatic arterial infusion in patients with nonresectable liver metastases from colorectal carcinoma. *J Clin Oncol* 2000;18:243–54.
2. Allen-Mersh TG, Earlam S, Fordy C, Abrams K, Houghton J. Quality of life and survival with continuous hepatic-artery floxuridine infusion for colorectal liver metastasis. *Lancet* 1994;344:1255–60.
3. Valeri A, Mini E, Tonelli P, Veneri F, Neri B, Borrelli D, et al. Intra-arterial hepatic chemotherapy with 5-fluorouracil and 5-methyltetrahydrofolate in the treatment of unresectable liver metastases from colorectal cancer. *Anticancer Res* 1994;14:2215–20.
4. Rougier P, Laplanche A, Huguier M, Hay JM, Ollivier HJ, Escat J, et al. Hepatic arterial infusion of floxuridine in patients with liver metastases from colorectal carcinoma: long-term results of a prospective randomized trial. *J Clin Oncol* 1992;10:1112–18.

5. Niederhuber JE, Ensminger WD. Surgical considerations in the management of hepatic neoplasia. *Semin Oncol* 1983;10: 135–47.
6. Huk I, Entsheff P, Prager M, Schulz F, Polterauer P, Funovics J. Patency rate of implantable devices during long-term intraarterial chemotherapy. *Angiology* 1990;41: 936–41.
7. Tanaka T, Arai Y, Inaba Y, Matsueda K, Aramaki T, Takeuchi Y, et al. Radiologic placement of side-hole catheter with tip fixation for hepatic arterial infusion chemotherapy. *J Vasc Interv Radiol* 2003;14:63–8.
8. Yamagami T, Iida S, Kato T, Tanaka O, Hirota T, Nakamura T, et al. Using n-butyl cyanoacrylate and the fixed-catheter-tip technique in percutaneous implantation of a port-catheter system in patients undergoing repeated hepatic arterial chemotherapy. *AJR Am J Roentgenol* 2002;179:1611–17.
9. Wacker FK, Boese-Landgraf J, Wagner A, Albrecht D, Wolf K-J, Fobbe F. Minimally invasive catheter implantation for regional chemotherapy of the liver: a new percutaneous transsubclavian approach. *Cardiovasc Intervent Radiol* 1997;20:128–32.
10. Clouse ME, Ahmed R, Ryan RB, Oberfield RA, McCaffrey JA. Complications of long term transbrachial hepatic arterial infusion chemotherapy. *AJR Am J Roentgenol* 1977;129:799–803.
11. Oberfield RA, McCaffrey JA, Polio J, Clouse ME, Hamilton T. Prolonged and continuous percutaneous intra-arterial hepatic infusion chemotherapy in advanced metastatic liver adenocarcinoma from colorectal primary. *Cancer* 1979;44: 414–23.
12. Herrmann KA, Waggershauer T, Sittek H, Reiser MF. Liver intraarterial chemotherapy: use of the femoral artery for percutaneous implantation of catheter-port systems. *Radiology* 2000;215:294–9.
13. Germer CT, Boese-Landgraf J, Albrecht D, Wagner A, Wolf KJ, Buhr HJ. The totally implantable minimally invasive hepatic arterial catheter for intraarterial chemotherapy of unresectable liver metastasis in cases of dysfunction of arterial access devices. *Chirurg* 1996;67:458–62.
14. Strecker E-PK, Boos IBL, Ostheim-Dzerowycz W, Heber R, Vetter SC. Percutaneously implantable catheter-port system: preliminary technical results. *Radiology* 1997;202:574–7.
15. Fiorentini G, Poddie DB, Giorgi UD, Guglielminetti D, Giovanis P, Leoni M, et al. Global approach to hepatic metastases from colorectal cancer: indication and outcome of intra-arterial chemotherapy and other hepatic-directed treatments. *Medical Oncology* 2000;17:163–73.
16. Doria MI, Doria LK, Faintuch J, Levin B. Gastric mucosal injury after hepatic arterial infusion chemotherapy with floxuridine. A clinical and pathologic study. *Cancer* 1993;74:2042–7.
17. Shike M, Gillin JS, Kemeny N, Daly JM, Kurtz RC. Severe gastroduodenal ulcerations complicating hepatic artery infusion chemotherapy for metastatic colon cancer. *Am J Gastroenterol* 1986;81:176–9.
18. Narsete T, Ansfield F, Wirtanen G, Ramirez G, Wolberg W, Jarrett F. Gastric ulceration in patients receiving intrahepatic infusion 5-fluorouracil. *Ann Surg* 1977;186: 734–6.
19. Niederhuber JE, Ensminger WD. Surgical considerations in the management of hepatic neoplasia. *Semin Oncol* 1983;10:135–47.
20. Cady B. Hepatic arterial patency and complications after catheterization for infusion chemotherapy. *Ann Surg* 1973;178:156–61.
21. Chuang VP, Wallace S, Stroehlein J, Yap HY, Patt YZ. Hepatic artery infusion chemotherapy: gastroduodenal complications. *AJR Am J Roentgenol* 1981;137:347–50.
22. Jewell LD, Fields AL, Murray CJW, Thomson ABR. Erosive gastroduodenitis with marked epithelial atypia after hepatic arterial infusion chemotherapy. *Am J Gastroenterol* 1985;80:421–4.
23. Wells JJ, Nostrant TT, Wilson JAP, Gyves JW. Gastroduodenal ulcerations in patients receiving selective hepatic artery infusion chemotherapy. *Am J Gastroenterol* 1985;80:425–9.
24. Kwee WS, Wils JA, Schlangen J, Nuyens CM, Arends JW. Gastric epithelial atypia complicating hepatic arterial infusion chemotherapy. *Histopathology* 1994;24:151–4.
25. Granmayeh M, Wallace S, Schwarten D. Transcatheter occlusion of the gastroduodenal artery. *Radiology* 1979;131: 59–64.
26. Yamagami T, Nakamura T, Iida S, Kato T, Nishimura T. Embolization of the right gastric artery prior to hepatic arterial infusion chemotherapy to prevent gastric mucosal lesions: approach via the hepatic artery versus the left gastric artery. *AJR Am J Roentgenol* 2002;179:1605–10.
27. Inaba Y, Arai Y, Matsueda K, Takeuchi Y, Aramaki T. Right gastric artery embolization to prevent acute gastric mucosal lesions in patients undergoing repeat hepatic arterial infusion chemotherapy. *J Vasc Interv Radiol* 2001;12:957–63.
28. Michels NA. Blood supply and anatomy of the upper abdominal organs. Philadelphia: Lippincott, 1955.
29. Reuter SR, Redman HC, Cho KJ. Gastrointestinal angiography, 3rd ed. New York: W. B. Saunders, 1986: 32–77.
30. Luzca G. X-ray anatomy of the vascular system. Budapest, Hungary: Butterworths, 1974: 224–93.
31. Hiramatsu K, Kouda E, Mouri M, Isobe Y. X-ray anatomy of the abdominal vascular system. Tokyo, Japan: Igaku-Shoin, 1982: 123–4.
32. Hashimoto M, Heianna J, Tate E, Kurosawa R, Nishii T, Mayama I. The feasibility of retrograde catheterization of the right gastric artery via the left gastric artery. *J Vasc Interv Radiol* 2001;12:1103–6.
33. Yamagami T, Kato T, Iida S, Hirota T, Nishimura T. Efficiency of the left gastric artery as a route for catheterization of the right gastric artery. *AJR Am J Roentgenol* 2005;184:220–4.
34. Yamagami T, Kato T, Iida S, Tanaka O, Nishimura T. Value of transcatheter arterial embolization with coils and n-butyl cyanoacrylate for long-term hepatic arterial infusion chemotherapy. *Radiology* 2004;230:792–802.
35. Yamagami T, Yoshimatsu R, Matsumoto T, Nishimura T. Redistribution of multiple hepatic arteries into a single hepatic artery to perform repeated hepatic arterial infusion chemotherapy. *Acta Radiol* 2008;49:513–20.
36. Seki H, Shiina M. Placement of a long tapered side-hole catheter in the hepatic artery: technical advantages, catheter stability, and arterial patency. *AJR Am J Roentgenol* 2006;187:1312–20.