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REVIEW ARTICLE

Complications of intraoperative radiofrequency ablation of liver metastases

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Abstract

Background: Intraoperative radiofrequency ablation (IRFA) of liver metastases can be used to treat patients with complex tumours that are unsuitable for parenchymal resection alone. This systematic review assesses the frequency, patterns and severity of complications associated with this procedure.

Methods: We carried out a bibliographic search on MEDLINE focused on IRFA for liver metastases, excluding hepatocarcinomas, and on intraoperative use, excluding percutaneous application.

Results: Thirty papers published between 1999 and 2007 were analysed. They covered a total of 2822 patients and 1755 IRFA procedures. The indications and techniques for IRFA differ from those for percutaneous treatment, as do associated results and complications. Specific complications associated with IRFA, such as liver abscesses, biliary stenoses and vascular thromboses, are directly correlated with the indications and associated procedures. Published results should be interpreted with caution as IRFA can be used alone or combined with parenchymal resection.

Conclusions: Specific complications related to IRFA are rare, especially for lesions of <35 mm in size located far from a main biliary duct, when additional septic procedures are not used. A lesion-by-lesion approach based on the benefit : risk ratio should therefore be used in the process of making surgical decisions. Combining resection with IRFA leads to higher morbidity, especially in difficult patients with numerous bilateral lesions, but may be necessary to achieve R0 (microscopically negative margins) outcomes.

Keywords

colorectal metastases < liver, non-colorectal metastases < liver, liver, resection < liver, radiological intervention/treatment < liver

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Introduction

Intraoperative radiofrequency ablation (IRFA) of liver metastases was first reported by Curley *et al.*[1] in 1999 and Elias *et al.*[2] in 2000. Promising initial results appeared to herald a new era in modern liver surgery.[3] However, unexpectedly, most of the teams who launched this technique in the late 1990s have since decided to forego IRFA[4–7] because of disagreement between hepatopancreatobiliary surgeons and radiologists. Radiologists have challenged the treatment of liver metastases by parenchymal resection only and proposed using percutaneous RFA (PRFA) as a minimally invasive alternative. In response, surgeons have simply decided to sacrifice both IRFA and PRFA at the same time. The results of PRFA are inferior to those of IRFA, especially in terms of local recurrence rates, and the presentation of combined outcomes for both techniques resulted in the exclusion of both.[8] In the same manner, Abdalla *et al.*[4] compared RFA with surgery, but allocated the easiest-to-treat lesions with wide margins to resection and the difficult-to-treat lesions to ablation, with unsurprising results: RFA, even via the intraoperative route, offered inferior results and hence its abandonment was recommended. Subsequently, and surprisingly, some published material[9] declared the absence of need for multicentre prospective studies, which, with less biased methodology, might have produced different results. Curiously enough,

in this same paper, Curley acknowledged that he continued to treat almost 10% of his patients with IRFA, indicating that perhaps the technique should not be discarded just yet.

In the last decade, efforts have focused mostly on learning about this treatment and most reports have been retrospective and have originated from expert centres. Data from two prospective studies, the CLOCC (Chemotherapy + Local Ablation Versus Chemotherapy for unresectable liver metastasis) Study[10] and the ARF2003 Study,[11] are to be published in 2010. Preliminary results from these are positive, despite a 22% lack of enrolment in the CLOCC Study. As a consequence, IRFA may enter an era of rejuvenation, in which its place in the surgical armamentarium is reserved on the strength of scientific evidence. Before we can embrace this new era, it is necessary to analyse the complications associated with IRFA by examining the available literature, mainly to explain how the best benefit : risk ratio can be determined for an individual patient. This review of the available IRFA literature covers 30 articles and identifies the frequencies, patterns and severity of complications associated with this procedure.

Materials and methods

Search strategy and selection criteria

A bibliographic search was conducted on MEDLINE. *Mesh* requests were: 'liver neoplasms' 'catheter ablation', 'laparotomy' and 'hepatectomy'. Additional keywords were added: 'intraoperative', 'coeliotomy' and 'open'. The exact request was: ('catheter ablation'[Mesh] AND 'liver neoplasms'[Mesh]) AND ('hepatectomy'[Mesh] OR 'laparotomy'[Mesh] OR 'intraoperative' OR 'open' OR 'coeliotomy').

The search was run in December 2008. Articles dealing exclusively with PRFA or with hepatocellular carcinoma (HCC) were excluded. Articles in all languages were accepted. Papers reporting complications of IRFA were selected and data were collected in a database (Microsoft Access 2003©). The following variables were recorded for each article.

Article characteristics

1 Title.
2 First author.
3 Year of publication.
4 Country of origin.

Population to be studied

1 Number of patients.
2 Number of IRFA procedures.
3 Average age of patients.
4 Frequency of cirrhotic patients.

Description of the diseases to be treated

1 Ratio of HCCs : metastases treated.
2 Size and number of lesions.

Description of complications

1 Mortality.
2 Liver failure.
3 Infections:
   - intra- and perihepatic abscesses;
   - peritonitis, and
   - abdominal wall abscesses.
4 Vascular complications:
   - haemorrhages and vascular injuries;
   - haematomas, and
   - portal thromboses.
5 Biliary complications:
   - bile collections;
   - bile leakages;
   - biliary stenoses, and
   - cholangitis.
6 Collateral lesions (or visceral lesions):
   - burns (biliary structures, digestive tract, diaphragm . . .);
   - injuries, and
   - pneumothorax.
7 Skin burns.
8 Pleural collections.

The terminology used was that recommended by the Interventional Radiology Technology Assessment Committee and the International Working Group on Image-Guided Tumour Ablation[12] updated by the Society of Interventional Radiology.[13]

Results

Our search retrieved 493 articles (Fig. 1). After exclusions for percutaneous-only treatment and HCCs, we selected 30 papers published between 1999 and 2007 (Table 1).[1,2,14–41] These papers covered a total of 2822 patients and 1755 IRFA procedures. In 961 of these procedures (54.8%), the lesions were treated by resection combined with IRFA. Complications were reported for series varying from five to 382 procedures. Only one series was a prospective multicentre study.[25] Eighteen articles were based on fewer than 50 patients.

In five papers[15,20,27,31,37] involving 450 patients and 343 IRFA procedures, IRFA was always combined with resection. In five other papers[16,21,28,33,35] (226 patients, 107 IRFA), no resections were performed in combination with IRFA. Only four papers reported frequencies of patients with cirrhosis (varying from 13.1% to 33.3%) and 22 articles reported frequencies of HCC, varying from none to 44.4%. The average lesion size (reported in 13 articles) ranged from 13 mm to 56 mm. Thirteen articles specified the mean number of lesions to be treated, which ranged from one to 6.2 lesions per patient.

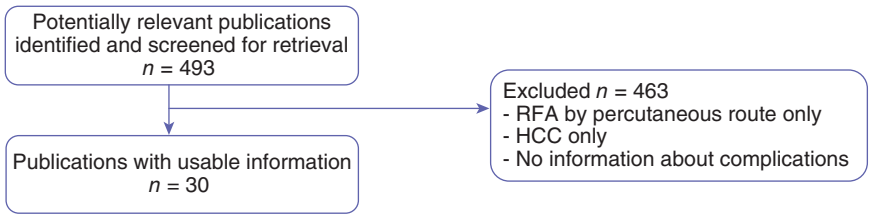

Figure 1 Details of methods used to select articles for the review of complications after intraoperative radiofrequency ablation of liver metastases. RFA, radiofrequency ablation; HCC, hepatocellular carcinoma

Table 1 Publications retrieved after a literature search for articles on intraoperative radiofrequency ablation of liver metastases

Author(s)	IRFA, *n*	HCC	Combined resection + IRFA	Mortality	Morbidity
Pearson *et al*. (1999)[32]	92	36.9%	19.5%	0%	3.3%
Curley *et al*. (1999)[1]	92	23.9%	19.5%	0%	3.2%
Jiao *et al*. (1999)[26]	30	20%	43.3%	3.3%	10%
Wood *et al*. (2000)[41]	39	–	51.2%	5%	5%
Elias *et al*. (2000)[2]	21	0%	80.9%	0%	47.6%
Wong *et al*. (2001)[40]	39	5%	48.7%	0%	20.5%
Risse *et al*. (2001)[34]	19	31.5%	52.6%	5.2%	26.3%
Stippel *et al*. (2002)[37]	23	0%	100%	0%	17.3%
Stella *et al*. (2002)[36]	21	19%	61.9%	0%	14.3%
Choy *et al*. (2002)[17]	12	–	75%	0%	33.3%
Pawlik *et al*. (2003)[31]	172	2.9%	100%	2.3%	19.8%
de Baere *et al*. (2003)[19]	124	–	95.1%	2.4%	9.6%
Bleicher *et al*. (2003)[15]	66	–	100%	0%	12.1%
Oshowo *et al*. (2003)[30]	16	0%	62.5%	0%	12.5%
Curley *et al*. (2004)[18]	382	14.6%	48.1%	0.52%	8.6%
Poon *et al*. (2004)[33]	56	–	0%	1.8%	16%
Tepel *et al*. (2004)[38]	26	–	42.3%	0%	27%
Basdanis *et al*. (2004)[14]	18	0%	11.1%	0%	0%
Jansen *et al*. (2005)[25]	108	10.6%	34.2%	1.8%	20.3%
Elias *et al*. (2005)[20]	63	0%	100%	0%	27%
Navarra *et al*. (2005)[29]	53	0%	22.6%	1.8%	14%
Ritz *et al*. (2006)[35]	6	0%	0%	0%	0%
Hildebrand *et al*. (2006)[22]	68	5.8%	52.9%	2.9%	7.3%
Hildebrand *et al*. (2006)[23]	64	–	56.3%	0%	12.5%
Chhabra *et al*. (2006)[16]	27	44.4%	0%	0%	3.7%
Low *et al*. (2006)[28]	13	–	0%	0%	0%
Gomez *et al*. (2006)[21]	5	–	0%	0%	0%
Topal *et al*. (2007)[39]	49	20.4%	24.5%	2%	34.7%
Hubert *et al*. (2007)[24]	32	12.5%	72%	0%	18%
Kornprat *et al*. (2007)[27]	19	0%	100%	5.2%	31.5%

IRFA, intraoperative radiofrequency ablation; HCC, hepatocellular carcinoma

Table 2 Morbidity rates in intraoperative radiofrequency ablation with or without resection

	All series, mean (min–max)	IRFA with resections, mean (min–max)	IRFA alone, mean (min–max)
Number of procedures, *n*	1755	343	107
Mortality	1.2% (0–5.2%)	1.5% (0–5.2%)	0.9% (0–1.8%)
Morbidity	13.6% (0–47.6%)	20.1% (12.1–31.5%)	9.3% (0–16%)
Wound infection	2.8% (0–13.4%)	3.5% (1.7–13.4%)	0.9% (0–1.8%)
Biliary complications	1.7% (0–9.5%)	3.8% (0–7.9%)	0.9% (0–1.8%)
Pleural effusion	1.4% (0–6.2%)	0.3% (0–0.6%)	1.9% (0–3.6%)
Liver failure	1.4% (0–14.2%)	2.6% (0–7.9%)	0.9% (0–1.8%)
Vascular complications	1.3% (0–5.3%)	0.6% (0–1.6%)	0.0% (0–0%)
Skin burns	0.5% (0–6.2%)	0.0% (0%)	0.9% (0–1.8%)
Collateral lesions	0.2% (0–1.5%)	0.6% (0–1.5%)	0.0% (0%)

Table 3 Morbidity rates in intraoperative radiofrequency ablation (IRFA) by size of series

	All series, mean (min–max)	Series with > 50 patients, mean (min–max)	Series with ≤ 50 patients, mean (min–max)
Number of procedures, *n*	1755	1340	415
Mortality	1.2% (0–5.2%)	1.1% (0–2.9%)	1.4% (0–5.2%)
Morbidity	13.6% (0–47.6%)	12.0% (2–27%)	18.8% (0–47.6%)
Wound infection	2.8% (0–13.4%)	2.7% (0–6.5%)	3.1% (0–13.4%)
Biliary complications	1.7% (0–9.5%)	1.3% (0–7.9%)	2.7% (0–9.5%)
Pleural effusion	1.4% (0–6.2%)	1.6% (0–6.2%)	0.7% (0–5.1%)
Liver failure	1.4% (0–14.2%)	1.3% (0–7.9%)	1.4% (0–14.2%)
Vascular complications	1.3% (0–5.3%)	1.4% (0–4.6%)	0.7% (0–5.3%)
Skin burns	0.5% (0–6.2%)	0.4% (0–4%)	0.7% (0–6.2%)
Collateral injuries	0.2% (0–1.5%)	0.3% (0–1.5%)	0.0% (0–0%)

Frequency of complications

Table 2 reports mortality and morbidity rates, as well as frequencies and types of complications, depending on whether or not IRFA was associated with resection. Table 3 presents the same results according to the size of the series.

Mortality

A total of 21 deaths were reported in 11 series,[18,19,23,25–27,29,31,33,39,41] with overall mortality varying from 0% to 5.2%. Four deaths were related to cirrhosis. Eleven occurred in patients undergoing resections, eight of which were major hepatectomies.

Causes of death are summarized in Fig. 2. Eight deaths were related to liver failure,[18,19,25,31,34,41] four of which were subsequent to major hepatectomy with IRFA on the remnant liver for bilobar disease.[18,19,31,41] Five deaths were caused by myocardial infarct;[18,23,39,41] one of these related to a carcinoid crisis[41] and another to a haemorrhage.[18] Four deaths resulted from portal thrombosis,[19,25,34] three of which occurred in cirrhotic patients.[19,34] One of these patients had been treated by IRFA alone.[34] Four deaths were related to septic complications; two of these referred to pulmonary infections,[26,31] one to infection of the ascites[25] and one to multiple deep abscesses.[25] Lastly, three deaths were reported after postoperative haemorrhaging;[18,25,31] one was caused by liver failure after an intrahepatic haematoma in a cirrhotic setting,[25] one resulted from myocardial infarction following a haemorrhage in a large metastasis treated by IRFA,[18] and one patient was treated by major hepatectomy and two IRFA sessions and died of cardiac arrest after postoperative bleeding.[31]

Infections

Abdominal infections were reported in 49 patients in 21 series.[9,15,17,18,20,22–27,29,31–34,36–38,40,41] Diagnosis of infection was delayed by up to 5 months.[25,41] Seventeen liver abscesses were reported, of which one was fatal[25] and 11 were related to IRFA. Only one case of biliary digestive anastomosis was observed.[22] Ten cases of perihepatic abscesses at resection sites were reported. Twelve were following digestive system-associated procedures. These abscesses were treated by percutaneous drainage and antibiotics. One patient needed re-operation and died from septic shock.[25] Seven cases[25,33,34,38,40] of wound infection were reported; two were re-operated.[25] Lastly, one case of peritonitis after infection of the ascites was reported and was fatal.[25]

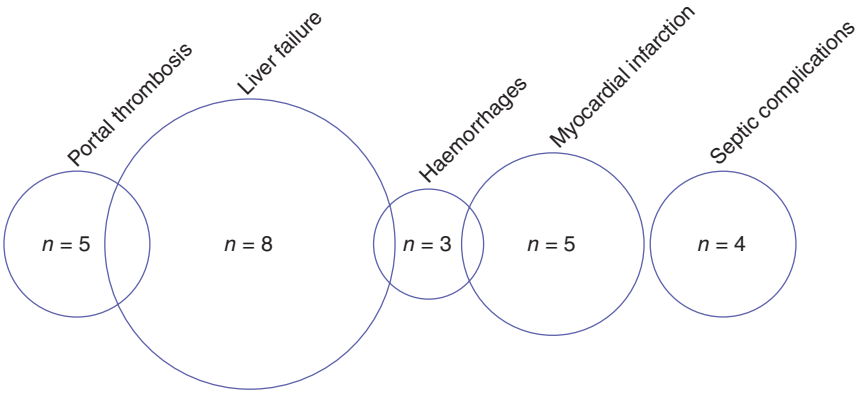

Figure 2 Causes of death reported in the literature after intraoperative radiofrequency ablation of liver metastases

Biliary complications

Twenty-five early (≤30 postoperative days) and 14 delayed (sometimes for >4 months[18]) biliary complications were reported in 10 series.[15,17,18,20,25,31,33,36,38,40] Twelve biliary leakages occurred, 10 of which were early. Six occurred in resection combined with IRFA. One early leakage was caused by a prophylactic cholecystectomy, but two delayed leakages were associated with a biliary stenosis.[18] Fifteen intrahepatic bile collections were described, one of which induced duodenal compression. One article[18] gave details of the treatment of eight biliomas: all eight were drained percutaneously and two recurred after drain clamping. Two were related to biliary stenoses and were treated by intrahepatic stenting; the other six patients underwent endoscopic sphincterotomy. Eleven biliary stenoses associated with jaundice and biliary dilatation were reported, of which five were early. These were complicated by biliomas,[18,25] biliary leakage[25] and cholangitis.[37] In their prospective study, Jansen *et al.*[25] did not observe a correlation between central or peripheric localization of the tumour and the frequency of biliary complications, by contrast with Curley *et al.*[18] Elias *et al.*[20] reported the efficiency of biliary cooling in five patients, which prevented biliary destruction in paraportal lesions.

Liver failure

Liver failure was reported in 24 patients in 11 articles[2,15,18–20,25,29,31,33,34,41] and was fatal in eight patients. Fourteen liver failures occurred after IRFA combined with major resection. Six liver failures occurred in cirrhotic patients; three of these failures occurred after IRFA alone.[18,34] Two liver failures were subsequent to portal thrombosis.[34]

Vascular complications

Different types of vascular complication were described in 11 articles in a total of 22 patients.[9,18,19,22,23,25,26,31,32,34,38] Associated procedures such as cholecystectomy or colectomy induced six haemorrhages, two of which were fatal[31,25] and one required re-operation after prophylactic cholecystectomy.[38] Three haemorrhages from the needle track were treated during surgery[18] by compression. In three cirrhotic patients, haemorrhage occurred in the necrosis induced by the IRFA; one patient died as a result.[25] Treatment of two juxta-portal lesions induced haemorrhages from arterial injuries.[25,26] In one patient, an arterio-portal fistula appeared in an area of necrosis 6 weeks later and was treated by a transfemoral embolization.[18] Similarly, a false aneurysm occurred in one patient 6 months after IRFA and led to a haemorrhage.[25] Five portal thromboses were reported,[19,25,34] four of which were complete and fatal. Three of these occurred in cirrhotic patients treated with Pringle vascular occlusion.[19,34]

Skin burns

Eight dispersive pad skin burns were reported in four articles.[16,19,30,38] Skin burns occurred when RFA ran for >30 min on high power and within large and multiple skin pads. One skin burn occurred in a patient with bilateral hip prostheses.[30] One third-degree skin burn required surgical treatment.[38]

Visceral damage

Two instances of thermal gastric damage[15,18] and one of acute cholecystitis near the gallbladder[25] were observed after IRFA during surgery and were treated immediately.

Discussion

On the whole, the methodologies used in the articles retrieved by the MEDLINE search were of a low scientific standard in terms of evidence-based research. All but one reported retrospective experiences and most involved only a single centre. The methodology used to report and describe complications was not standardized and mixed low and high grades of complication severity at different durations of follow-up. Consequently, the data obtained cannot be compared with those reported in studies that define complications according to classifications such as that described by Dindo *et al.*[43] In addition, the populations studied were heterogeneous and it is thus impossible to calculate a confidence interval

Table 4 Comparison of morbidity rates in intraoperative radiofrequency ablation (IRFA) and percutaneous radiofrequency ablation (PRFA)

	IRFA, mean (min–max)	IRFA without resection, mean (min–max)	PRFA, mean[a]
Number of procedures, *n*	1755	107	3670
Mortality	1.2% (0–5.2%)	0.9% (0–1.8%)	0.5%
Morbidity	13.6% (0–47.6%)	9.3% (0–16%)	8.9%
Wound infection	2.8% (0–13.4%)	0.9% (0–1.8%)	1.1%
Biliary complications	1.7% (0–9.5%)	0.9% (0–1.8%)	1.0%
Liver failure	1.4% (0–14.2%)	0.9% (0–1.8%)	0.8%
Vascular complications	1.3% (0–5.3%)	0.0% (0–0%)	2.2%
Skin burns	0.5% (0–6.2%)	0.9% (0–1.8%)	0.6%
Visceral damage	0.2% (0–1.5%)	0.0% (0–0%)	0.5%

[a]Results of PRFA were extracted from the review by Mulier *et al*.[44] Minimum and maximum data were not available for PRFA

for the means. Nevertheless, the different types of complication reported are relatively similar across studies, which allows us to assume a common general profile of the morbidity associated with this technique.

Comparison with PRFA

Percutaneous RFA is a recommended treatment for HCC in cirrhotic patients. This procedure differs from IRFA in terms of indications, techniques, results and morbidity. Table 4 summarizes the different morbidities associated with IRFA and PRFA. Results for PRFA were extracted from the literature review conducted by Mulier *et al*., which reported 3670 RFA procedures, 2898 (78.9%) of which were PRFAs.[44] Mortality and morbidity rates after PRFA were lower than after IRFA (0.5% and 8.9% vs. 1.2% and 13.6%, respectively) when all patients receiving IRFA were considered. However, when mortality and morbidity rates in patients who received PRFA were compared with those in patients who received only IRFA, thus excluding the effects of surgery, mortality and morbidity rates were similar (0.5% and 8.9% vs. 0.9% and 9.3%, respectively).

The open procedure not only allows complete abdominal exploration, but also enables visceral protection or immediate reparation of visceral damage. However, Mulier *et al*. reported two cases of gastric wall burns after IRFA.[44] These complications were diagnosed and treated successfully during the procedures. Only one case of cholecystitis occurring after IRFA near the gallbladder was reported. Prophylactic cholecystectomy may prevent this complication, but specific vascular and biliary complications may occur. As a result, systematic prophylactic cholecystectomy cannot be recommended, but should be performed only for IRFA near the gallbladder. Finally, specific complications, such as wound infections, evisceration and abdominal dehiscence, are associated with laparotomy.

Comparison with hepatectomy

The morbidity of hepatectomy depends on the extent and complexity of the hepatic resection. Intraoperative RFA as a stand-alone treatment is indicated for unresectable tumours in patients in whom major hepatectomy would leave a low level of functional hepatic reserve. Mortality and morbidity rates in major hepatic resection are 0–5% and 20–50%, respectively.[45] Rates of liver failure after major hepatectomy preceded by portal embolization are 4–10%[46,47] vs. 2.6% after IRFA combined with hepatic resection. Pawlik *et al*. reported mortality of 2.3% and morbidity of 19.8% in patients treated by resection and combined IRFA, and estimate their results to be comparable with those of resection alone.[31] Morbidity rates after major hepatic resection and IRFA combined with hepatic resection are comparable, even if IRFA is indicated in tumours unresectable by hepatectomy alone.[48] Table 5 summarizes differences in morbidity in patients undergoing hepatectomy alone and hepatectomy combined with IRFA, illustrating the great similarity between the techniques.

Specific complications of IRFA

Some complications are specific to RFA and thus can also be induced by IRFA. Hepatic abscesses are caused by infection of the necrotic tissue in the RFA site. They appear after an asymptomatic period ranging from 8 days to 5 months.[19,41,49] Imaging examinations detect a lot of gas in the necrotic zone, which indicates an abscess. However, the presence of a low quantity of gas is usual in the necrotic zone during the month after RFA.[50] Despite the fact that, in our experience, an additional septic procedure such as colectomy has a major role in the occurrence of such a complication, this has never been reported in the literature. It may be that special prophylaxis antibiotics are indicated in such cases. Diabetes mellitus and bilioenteric anastomosis are recognized risk factors for hepatic abscess after liver ablation procedures and the risk for abscess is estimated to be 40–50% in the presence of bilioenteric anastomosis.[19,51] Biliary colonizations (antecedents of sphincterotomy, biliary stent, biliary stenoses, etc.) are other possible risk factors.[44] Such abscesses should be treated by antibiotics and percutaneous drainage, and sometimes by re-operation. Only symptomatic biliary leakage such as infection or bowel compression should be treated by percutaneous drainage. In cases of asso-

Table 5 Comparison of morbidity rates after intraoperative radiofrequency ablation (IRFA) with those after hepatectomy

	All series, mean (min–max)	IRFA combined with resection, mean (min–max)	Hepatectomies, min–max[a]
Number of procedures, *n*	1755	343	NA
Mortality	1.2% (0–5.2%)	1.5% (0–5.2%)	0–5%
Morbidity	13.6% (0–47.6%)	20.1% (12.1–31.5%)	20–50%
Wound infection	2.8% (0–13.4%)	3.5% (1.7–13.4%)	1–9%
Biliary complications	1.7% (0–9.5%)	3.8% (0–7.9%)	3–4%
Pleural effusion	1.4% (0–6.2%)	0.3% (0–0.6%)	5–10%
Liver failure	1.4% (0–14.2%)	2.6% (0–7.9%)	1–5%
Vascular complications	1.3% (0–5.3%)	0.6% (0–1.6%)	1–3%
Skin burns	0.5% (0–6.2%)	0.0% (0–0%)	
Visceral damage	0.2% (0–1.5%)	0.6% (0–1.5%)	

[a]Results on hepatectomies were extracted from a review by Fong,[45] in which only extreme values are given
NA, not applicable

ciated biliary stenosis, intrahepatic stenting or endoscopic sphincterotomy should be considered.

Biliary stenoses appear after the fibrous healing of biliary tract thermal damage. They are diagnosed by imaging survey. Many of these biliary stenoses are asymptomatic and do not require treatment.[52] Only biliary stenoses that occur near the major biliary tract after RFA are symptomatic[18,44] and can be treated by intrahepatic stenting or endoscopic sphincterotomy. Vascular occlusions do not affect the frequency of biliary complications, although experimental studies have suggested that vessels protect the biliary tract by a 'heat sink' effect.[53] Biliary refrigeration may protect against biliary complications, but the oncological impact remains to be evaluated.[54]

Intraoperative bleeding from the needle track can be treated during surgery by manual compression. Postoperative haemorrhages sometimes require emergency re-operation or transfemoral embolization, and may lead to death if care is not immediately possible.

Vascular thromboses after IRFA are caused by thermal endothelial damage. Experimental studies suggest that vascular occlusion increases the risk for vascular thrombosis, especially when the distance is <5 mm.[55] Mulier *et al.* confirmed this hypothesis in their literature review.[44] Portal thromboses are more frequent in cirrhotic patients and may be complicated by liver failure and fatal issue.[19] Thrombosis of veins of <3 mm in diameter is common after IRFA. It is asymptomatic and spontaneous regression is often observed after 2 months.[19]

Skin burns occur when the dispersion surface is inadequate for the radiofrequency power. Goldberg *et al.* recommend that multiple (e.g. four) large dispersive pads should be placed at equal distances of 50 cm from the RFA site to prevent skin burns.[56]

Conclusions

The past 10 years have represented a period of learning for surgeons who deal with liver metastases with the aim of treating more patients by combining IRFA with resection. The benefit : risk ratio is now well known and surgeons have access to the knowledge they need to make more informed choices about whether to resect, ablate or renounce treatment on a lesion-by-lesion basis. Surgeons who are skilled in intraoperative ultrasound diagnosis and guidance are now not only able to choose whether or not to perform surgery, but are also able to perform IRFA and do not need to involve a radiologist.

Specific complications related to IRFA are rare, especially if the lesion is <35 mm in diameter and is located far from a main biliary duct and no additional septic procedures are used. The surgeon can decide to ablate a lesion in a more difficult situation, but this carries greater risk. Combining resection with IRFA leads to higher morbidity, especially in difficult patients with numerous bilateral lesions, but this may be necessary to achieve R0 (microscopically negative) resection margins. The final results of the CLOCC Trial and the ARF2003 Study will shortly become available and will help to define the proper place of IRFA in the surgical armamentarium.

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Conflicts of interest

None declared.

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