ORIGINAL ARTICLE

Computed Tomography–guided Percutaneous Radiofrequency Ablation of Adrenal Tumours: Five-year Institutional Review on Safety and Technique

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ABSTRACT

Objective: *Computed tomography–guided radiofrequency ablation is an emerging minimally invasive therapy for solid organ neoplasms. This study aimed to evaluate our technical and safety experience with this procedure when used for the ablation of adrenal tumours.*

Methods: *Records of all patients who had computed tomography–guided radiofrequency ablation of adrenal tumours performed in our department between August 2004 and August 2009 were retrospectively reviewed. Individual tumour characteristics, procedural technique, complications, and subsequent management were assessed.*

Results: *In all, 56 computed tomography–guided radiofrequency ablations of adrenal tumours (59% Conn's adenomas, 20% Cushing's adenomas, 21% metastases; mean maximal dimension, 2.5 cm) were performed in 49 patients (24 males, 25 females; mean age, 53 years). Four patients had more than one session of radiofrequency to achieve complete tumour ablation. Most commonly, a prone paraspinal approach was employed in 70%; decubitus paraspinal and transhepatic approaches were used in 21% and 9% of the instances, respectively. In eight (14%) of the instances, an iatrogenic pneumoretroperitoneum was induced or a hydrodissection was performed in order to position the adrenal more favourably for electrode insertion. In three (5%) of the instances, attempted insertion failed. Fourteen (25%) of the procedures resulted in minor complications, which included seven retroperitoneal haematomas (size, 0.5-4 cm) and six small pneumothoraces. One patient endured a hypertensive crisis. The median hospital stay for our patients was two days.*

Conclusion: *Apart from one patient who had a hypertensive crisis, no other major morbidity or mortality was observed. Computed tomography–guided radiofrequency ablation of adrenal tumours can be technically challenging for those with an unfavourable anatomy. However, compared to currently employed standard forms of open or laparoscopic surgery, it was associated with a lower complication rate and shorter hospital stay, and can therefore be considered a safe procedure in experienced hands.*

Key Words: *Adrenal cortex neoplasms; Adrenal gland neoplasms; Catheter ablation; Tomography, X-ray computed*

中文摘要

CT導引下經皮射頻消融術治療腎上腺腫瘤的安全性及技術層面：
五年本地經驗

唐倩儂、李嘉樂、李醒芬

目的：CT導引下經皮射頻燒融術是治療實質器官腫瘤的一種新興微創術。本研究評估此技術治療腎上腺腫瘤的安全性及技術層面。

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方法：回顧2004年8月至2009年8月期間於本院進行CT導引下經皮射頻消融術治療腎上腺腫瘤的病人紀錄。並分析其腫瘤特徵、技術程序、併發症及其後的跟進。

結果：49名腎上腺腫瘤病人（24男、25女；平均年齡53歲）共進行56次CT導引下經皮射頻消融術，包括Conn's腺瘤（59%）、Cushing's綜合症（20%）、轉移瘤（21%）；腫瘤平均最大徑為2.5 cm。有4名病人要進行超過一次的消融術來把腫瘤徹底清除。大多數採用俯伏式椎旁切口（70%），其餘採用臥位椎旁切口（21%）及經肝方法（9%）。為更易把電導管插入腫瘤，8例（14%）進行腹膜後腔積氣或水分離的方法。3名病人（5%）最終不能把電導管插入。14例（25%）有輕微併發症，包括7例出現腹膜後血腫（0.5至4 cm大小）及6例出現氣胸，另1例有高血壓危象。病人住院中位數為兩天。

結論：除了1人有高血壓危象外，其餘病人均無嚴重疾病或死亡。CT導引下經皮射頻消融術治療腎上腺腫瘤對於一些解剖困難的病人會有技術困難。與傳統標準的開胸或腹腔鏡手術比較，此消融術有相對較低的併發率及較短的住院期。對於有豐富經驗的醫生來說，此技術是安全的。

INTRODUCTION

Computed tomography (CT)–guided radiofrequency ablation (RFA) is an emerging minimally invasive therapy for neoplasms of various organs, including liver, bone, kidney and lung, where its results appear promising in terms of both safety and efficacy.[1-8] After placement of the needle electrode into the tumour mass under image guidance, a high-frequency alternating current is delivered, thereby exploiting ionic agitation, which generates frictional heat for cell destruction at a predictable temperature and in a predictable volume of tissue. Increasing numbers of publications report the successful application of RFA for adrenal tumours, including primary adrenocortical carcinomas, adrenal metastases, and functional tumours (aldosteronomas, Cushing's adenomas, and pheochromocytomas).[9-15] However, the position of the adrenal gland can make adrenal tumours anatomically challenging for percutaneous ablation. Not surprisingly, there are reports that the procedure can induce life-threatening hypertensive crisis.[15-17] These are of particular concern, even though their occurrence is rare. The aim of this study was to evaluate the technical and safety aspects of CT-guided RFA of adrenal tumours in our institution.

METHODS

Records of all patients with adrenal tumours that were referred to our department for CT-guided percutaneous RFA between August 2004 and August 2009 were retrospectively reviewed. Informed consent was obtained from all patients before they had undergone the procedure. The characteristics of their adrenal lesions, procedural techniques, complications, subsequent management, and the length of hospital stay were assessed. The entire study was approved by the local ethics committee.

RESULTS

Patient Demographics and Tumour Characteristics

A total of 56 referrals (24 male and 25 female) for CT-guided percutaneous RFA of adrenal tumours were received in our department during the five-year study period (Table 1). The adrenal tumours included: 33 (59%) Conn's adenomas, 11 (20%) Cushing's adenomas, and 12 (21%) metastatic lesions; they had a mean (standard deviation [SD]) maximal dimension of 2.5 cm (1.4 cm). The diagnoses were made based on biochemical and radiological findings. The mean (SD) age of the patients was 53 (10) years. Two patients had bilateral lesions, which were metastatic (Table 2). Four patients underwent more than one RFA session for complete ablation of the residual or recurrent adrenal tumour.

Procedural Techniques

All of the CT-guided RFAs were performed in the Prince of Wales Hospital (a tertiary university hospital)

Table 1. Patient demographics and tumour characteristics.

Nature of adrenal lesions	No. of cases	Mean ± standard deviation (range)	
		Patient age (years)	Maximal dimension (mm)
Conn's adenoma	33	51 ± 9 (29-67)	17 ± 5 (6-30)
Cushing's adenoma	11	53 ± 2 (38-76)	27 ± 6 (16-44)
Metastasis	12	60 ± 7 (48-70)	44 ± 16 (14-70)
Total	56	53 ± 10 (29-76)	25 ± 14 (6-70)

by a designated interventional radiologist with more than 10 years of relevant experience. The procedures involved either a 17G Cool-Tip™ single-needle electrode (Valleylab™, Tyco Healthcare Group, USA) connected to a Cool-Tip™ Generator (89%), or a 17G LeVeen CoAccess™ needle electrode (BostonScientific, USA) connected to an RF3000® Generator (13%). These devices are all approved by the US Food and Drug Administration and accepted in clinical practice for treatment of focal malignancies. Different needle exposure penetrations were selected depending on the size of the respective adrenal tumour. For the Cool-Tip™ electrode, the needle tip exposure penetration was 1 cm in 13%, 2 cm in 83%, and 3 cm in 4% of instances. The LeVeen CoAccess™ electrode tended to be used for larger lesions; the exposure penetration was 2 cm in 14%, 3.5 cm in 14%, 3 cm in 57%, and 4 cm in 14% (Table 3).

All patients were given a prophylactic dose of an intravenous antibiotic (cefuroxime 1.5 g or ciprofloxacin 200 mg) immediately before the procedure. Pre-emptive analgesia in the form of intravenous pethidine (median, 50 mg; range, 25-75 mg) was given at the beginning of the procedure. Local anaesthetic (1-5 ml of 2% lignocaine) was also given to all patients.

The needle electrode was inserted in a standard stepwise manner under the guidance of a 64-detector-row CT scanner (GE medical system). With respect to the approach for insertion of the needle electrode, a prone paraspinal approach (Figure 1) was most commonly employed (in 70% of instances); the needle was inserted through the retroperitoneal/perinephric fat between the spine and the ipsilateral kidney. Other approaches included the decubitus paraspinal (21% of instances; Figure 2), either ipsilaterally (15%) or contralaterally (6%); and the transhepatic (9%). The transhepatic approach was performed with or without additional ultrasound guidance.

Despite the different patient positionings used, for eight (14%) of the instances iatrogenic

Table 2. Metastatic adrenal lesions: site of primary tumour and side of adrenal metastasis.

| Site of primary tumour	No.	Side of adrenal metastasis		
		Right only	Left only	Bilateral
Hepatocellular carcinoma	2	1	-	1
Tongue and oesophageal carcinoma	1	-	-	1
Gastric carcinoma	1	1	-	-
Lung adenocarcinoma	1	-	1	-
Colonic carcinoma	1	1	-	-
Leiomyosarcoma	1	1	-	-

Table 3. Procedural technique.

Nature of adrenal lesions	Special techniques* (RA:CO₂:D5)	Type of electrode (C-T:LV)†	Median (range) electrode tip exposure (cm)
Conn's adenoma	6 (4:1:1)	30:0	2 (1-2)
Cushing's adenoma	2 (2:0:0)	10:1	2 (1-3)
Metastasis	0	6:7	2.5 (2-4)
Total	8 (6:1:1)	46:8	2 (1-4)

Abbreviations: RA = room air, CO_2 = carbon dioxide, D5 = 5% dextrose solution.

* Special techniques used to make the adrenal position more favourable for electrode insertion by means of iatrogenic retropneumoperitoneum or hydrodissection.

† Type of electrode used: C-T = 17G Cool-Tip™ single-needle electrode, LV = 17G LeVeen CoAccess™ needle electrode.
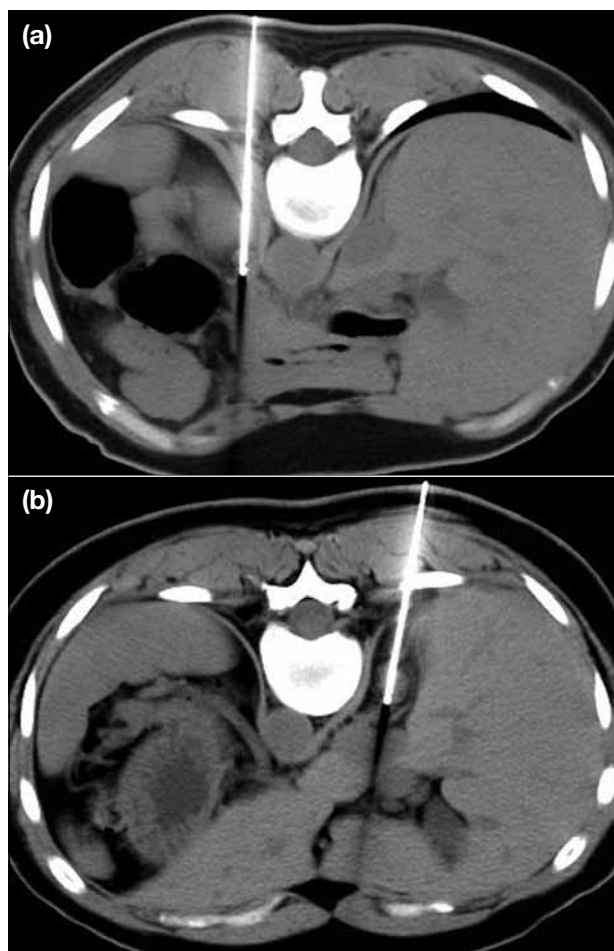
Figure 1. Cool-Tip™ electrode inserted into (a) the left and (b) the right adrenal gland in two different patients using a prone paraspinal approach.

pneumoretroperitoneums or hydrodissections were induced to position the adrenal more favourably for needle insertion. This was achieved by injecting 120 ml to 250 ml of either 5% dextrose solution (Figure 3), room air (Figure 4), or carbon dioxide into the retroperitoneal space, using an 18G or 19G spinal needle, and thereby displace adjacent structures. In six of these instances, successful ablation of the adrenal tumour was achieved, whilst in two of the patients the anatomy remained unfavourable.

In three (5%) of the instances, attempted ablation failed due to unfavourable anatomy despite different positionings and different approaches. These were all patients with small left-sided Conn's adenomas (mean ± SD maximal dimension, 12 ± 6 mm) lying too close to adjacent structures to enable safe access.

After successful placement of the needle electrode, ablation was performed in all patients using the standard impedance-control algorithm until 'roll-off'. Heating of soft tissue above 50°C caused numerous changes at the cellular level, including denaturation of protein and desiccation (loss of intracellular fluids), which reduces the ability of the soft tissue cells to conduct an electrical current.[18,19] This increase in tissue impedance gradually rises to a point, where the current is no longer transmitted, known as 'roll-off', indicating tumour coagulation. The patient then has an immediate non-contrast CT scan of the adrenal lesion to assess whether the tumour was completely covered by the ablative field. Successful ablation was indicated by evidence of coagulative necrosis, which appears to be more hypodense. Occasionally though, the lesion may become more hyperdense as a result of haemorrhage. In nine patients with large adrenal tumours (4 with Cushing's adenomas and 5 with metastatic lesions; mean ± SD maximal dimension, 41 ± 19 mm), additional cycles of ablation were performed within the same session. These were performed after

Figure 2. Cool-Tip™ electrode inserted into the right adrenal gland with the patient in ipsilateral decubitus position using a paraspinal approach.
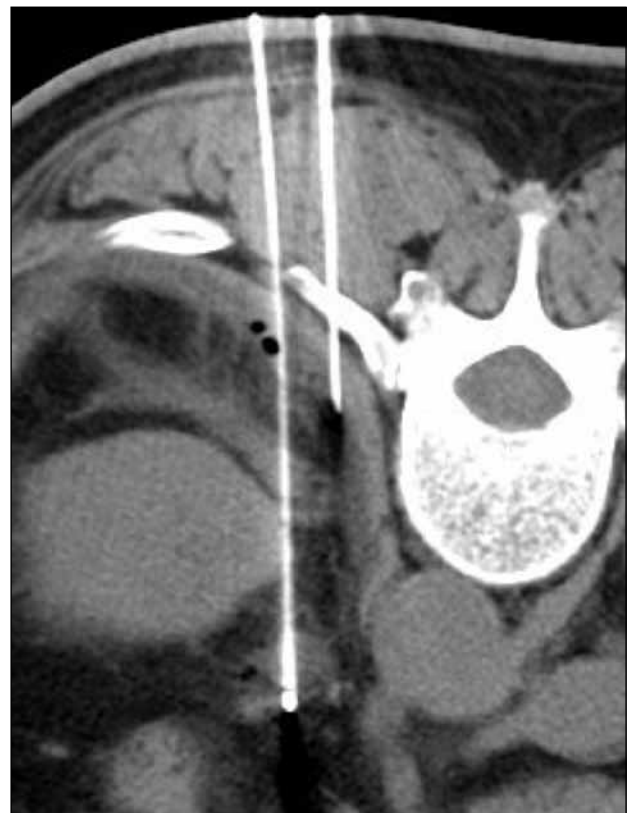
Figure 3. A spinal needle (medially located) was first inserted for retroperitoneal hydrodissection using 5% dextrose solution. This successfully displaced the left kidney laterally, which allowed a safe path for insertion of the Cool-Tip™ (laterally located) electrode into the left adrenal gland.

re-positioning of the needle electrode, so as to attain complete ablation of the tumour.

For the metastatic lesions, at intervals the needle tract was also ablated. Thus, after ablation of the tumour, the needle electrode was retracted slightly along its tract, whereupon ablation was again performed until 'roll-off'. The needle was then again retracted slightly along its tract and another ablation performed until 'roll-off'. This process was repeated until the needle was completely retracted. In this way, it was possible that tumour seeding along the needle tract was theoretically ablated upon needle removal, so as to reduce the theoretical risk of seeding.

Apart from one instance, the bilateral lesions were treated in separate CT-guided RFA sessions. Three patients had two sessions of RFA for complete ablation of the residual or recurrent tumour (1 metastatic lesion, 1 Conn's adenoma, and 1 Cushing's adenoma). One metastatic lesion was subjected to three ablative sessions. The remaining adrenal tumours were completely ablated in one session.

Complications

Fourteen (25%) of the instances developed minor complications, which all resolved spontaneously with no medical treatment or surgical intervention (Table 4). Seven (13%) acquired retroperitoneal haematomas (ranging from 0.5 to 4 cm in diameter; Figure 5), and six (11%) entailed small pneumothoraces (Figure 6). One patient had both of these complications.

After ablation of a small Conn's adenoma close to the left adrenal, one patient developed a small non-enhancing area in the upper pole of left kidney (revealed by a follow-up contrast CT). No inflammatory changes were evident and the features were suggestive of a small focal infarction. There was no deterioration in the renal function, the putative infarcted region being very small. The appearance of this lesion remained static on subsequent follow-up CT scans, which was also considered to be a minor complication.

One 63-year-old woman with multiple medical conditions (including diabetes mellitus, hypertension, ischaemic heart disease, congestive heart failure, atrial fibrillation, and sleep apnoea) developed transient hypertension (systolic pressure of >180 mm Hg) during ablation of her Cushing's adenoma. As there was no further rise in her blood pressure and the patient was asymptomatic, she was treated conservatively and her


Figure 4. (a) The left adrenal gland was initially in an unfavourable in position and did not allow a safe prone paraspinal approach, as the path was obstructed by the upper pole of the left kidney. (b-c) After creating an artificial pneumoretroperitoneum, the left kidney was displaced laterally, allowing a safe path for insertion of the Cool-Tip™ electrode into the left adrenal gland.

**Table 4.** Complications and length of hospital stays.

Nature of adrenal lesions	Complications				Mean (± standard deviation) length of stay (days)
	Haematoma	Pneumothorax	Renal infarct	Hypertensive crisis	
Conn's adenoma	4	3	1	0	3 ± 1
Cushing's adenoma	2	2	0	1	4 ± 1
Metastasis	1	1	0	0	2 ± 0
Total	7	6	1	1	3 ± 1

blood pressure was closely monitored. The systolic pressure slowly dropped back down, and the ablative cycle was continued until its completion at 12 minutes. As the transient hypertension occurred during the procedure, this was considered a procedure-related hypertensive crisis. The patient was otherwise well and remained asymptomatic throughout the procedure. However, she developed chest pain and shortness of breath when transferred back to the ward. At this point she was diagnosed as having acute coronary syndrome precipitated by a hypertensive crisis (troponin T, 0.11 µg/L [normal level, <0.03 µg/L]); electrocardiography showed no new or serial changes. She was immediately started on aspirin, low-molecular-weight heparin and an isosorbide dinitrate infusion and her condition gradually improved. Her hospital stay was prolonged to 5 days. Her blood pressure was 120/70 mm Hg upon discharge.
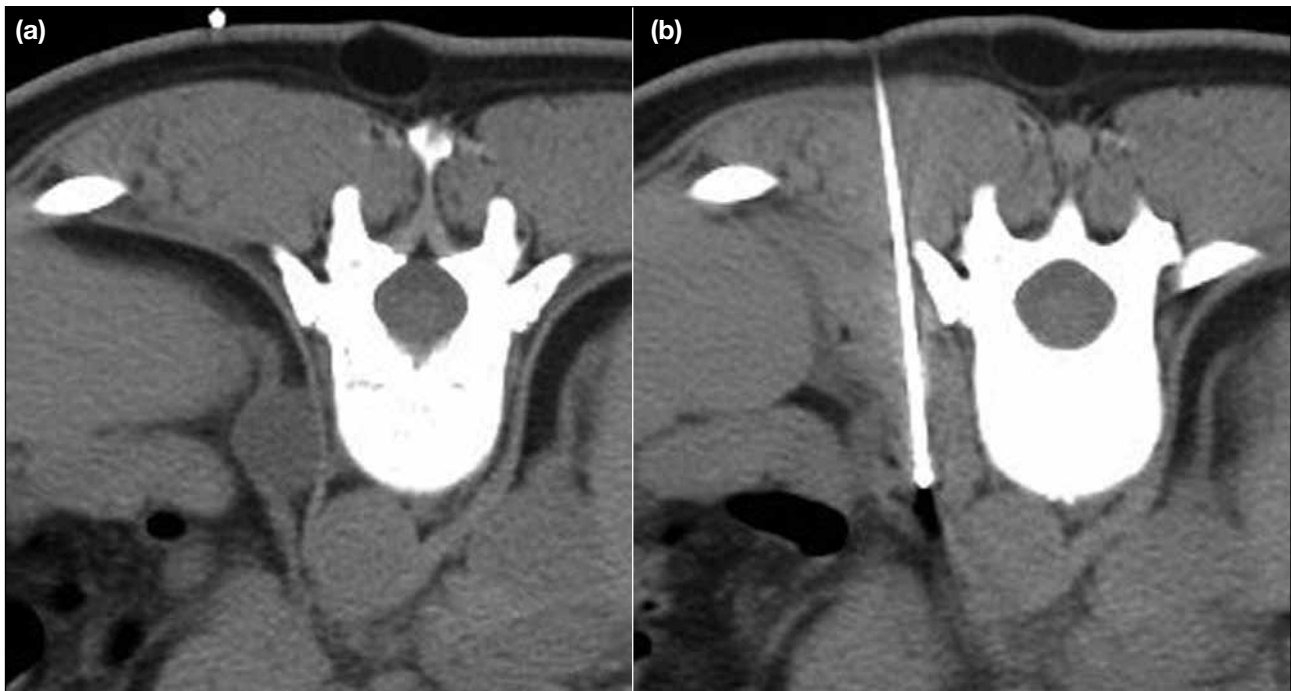
Figure 5. (a) Hypodense left adrenal adenoma before the procedure; the retroperitoneal fat space was clear. (b) After insertion of the Cool-Tip™ electrode, a small left retroperitoneal haematoma developed along the tract of the needle electrode, probably due to minor vascular injury during needle insertion. This haematoma subsequently resolved with conservative treatment.
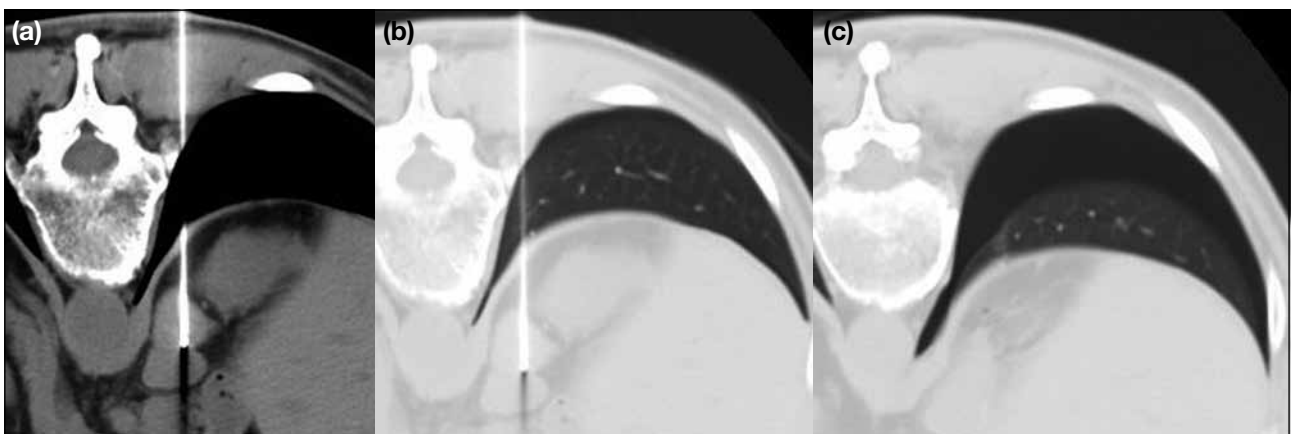
Figure 6. (a) The Cool-Tip™ electrode was successfully placed into the right adrenal gland using a prone paraspinal approach, however, its path traversed the right lung base. (b) A small rim of pneumothorax developed immediately, and gradually increased during the procedure. The patient remained asymptomatic with stable vital signs, and so ablation was continued until completion. (c) After the needle electrode was removed, its tract across the lung base and the injury it caused could be well-appreciated on computed tomography. The pneumothorax subsequently resolved with conservative treatment.
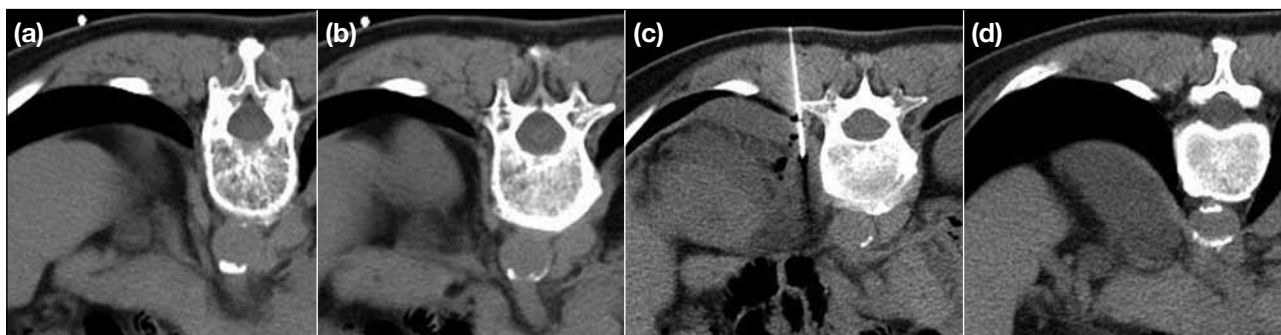
Figure 7. (a-b) The left adrenal gland was closely related to the spleen, the upper pole of the left kidney and pancreatic tail, all due to lack of retroperitoneal fat. (c) A spinal needle was inserted into the left retroperitoneal space for hydrodissection with 5% dextrose solution, which successfully displaced the kidney laterally and inferiorly. (d) However, a prone paraspinal approach was still not feasible, as the electrode insertion path would traverse a significant amount of the left pleural space. The adrenal lesion also remained closely related to the adjacent pancreatic tail and vasculature. Rescanning the patient after decubitus positioning also failed to create a safe path for electrode insertion. The procedure was therefore abandoned.

Overall, the median and mean hospital stay for our patients was 2 and 2.6 days, respectively (SD, 1.0 day). There was no procedure-related mortality.

DISCUSSION

The complication rate of CT-guided RFA for adrenal tumours at our centre was 25% for minor morbidities and 2% for hypertensive crisis leading to acute coronary syndrome. Regarding minor complications, apart from a possible small renal infarct, which remained static, the pneumothoraces and retroperitoneal haematomas all resolved spontaneously on conservative treatment. No other morbidity or mortality ensued. By contrast, for the currently performed standard of laparoscopic adrenalectomy, the risk of major vascular and visceral injuries are reported to be as high as 18.5% and 6.4%, respectively; mortality is reported to be 0.2%.[20] Thus, CT-guided RFA may be considered a comparatively safe procedure.

The median and mean hospital stays in our series of patients was 2 days and 2.6 days, respectively, of which the figures were shorter than the respective reported stays of 2.9 days to 7.2 days for laparoscopic adrenalectomy.[20]

Risk of Injury to the Adjacent Structures

The safety of CT-guided RFA depends on the careful selection of the needle electrode and the approach to needle insertion. Ideally, the patient should be prone and the most direct route to the adrenal gland is paraspinal. If this path is obstructed, the patient should be rescanned after either ipsilateral or a contralateral decubitus positioning, to assess whether the obstruction lies outside the needle path and could allow safe paraspinal insertion. Other means of displacing any obstructing structure in the needle's path entails creating an artificial retropneumoperitoneum (using room air or carbon dioxide) or hydrodissection (using 5% dextrose solution). Such techniques have also been described as proven to be useful in the literature.[12,21,22] Ionic solutions should not be used for hydrodissection, as the free ions can conduct the radiofrequency current and cause heat injury.

Sometimes the path to the adrenal gland remains obstructed despite these techniques, and to reach the adrenal tumour transecting the liver may be unavoidable to achieve adequate electrode positioning. This occurred most commonly in patients with a wide dorsal pleural recess, which rendered a paraspinal approach impossible without traversing the lung base. In our series, no significant hepatic injury (such as bleeding) ensued, which was similar to other reports in the literature describing the use of this technique.[14,15,23,24]

A transpleural or transpulmonary approach should be avoided in patients with reduced pulmonary function. Inadvertent needle puncture of the lung base related to the patient's breathing sometimes occurs during the procedure. Prior training of the patient in proper breathholding can help to reduce such complications. An ipsilateral decubitus position causes compression of the dependent ipsilateral lung, which also minimises the need to traverse the lung parenchyma.[11] In our series, pneumothoraces resulting from lung base transection by the needle electrode were all small, and they all resolved spontaneously with conservative treatment.

Figure 8. The Cool-Tip™ electrode was placed in the right adrenal gland using a transhepatic approach. This was to avoid the closely related upper pole of the right kidney and also allow better alignment of the electrode tip with the long axis of the adrenal lesion.

Retroperitoneal / perinephric fat surrounding the adrenal gland serves as a heat insulator, which prevents heat injury to adjacent structures. Problems arise when the adrenal gland lies too close to adjacent organs or vasculature. In some patients, this may be related to the position of the adrenal gland, or the lack of adequate retroperitoneal fat. In these circumstances, the procedure becomes much more technically challenging, and if the aforementioned techniques do not provide a safe path for needle insertion, percutaneous ablation should be abandoned (Figure 7).

Different tip exposures were selected according to the size of the tumour, so that larger lesions can be adequately ablated; for the smaller lesions, the structures adjacent to the adrenal gland need not be ablated unnecessarily. If a small tip exposure is used for a large tumour, then the ablation process needs to be repeated with needle re-positioning (between each cycle) to ensure complete ablation. These manoeuvres tend to prolong the procedure unnecessarily, and hence an appropriate tip exposure should be selected.

Apart from the location of the adrenal gland and its relationship to adjacent major structures, its orientation also determines how the needle electrode should be inserted. As the ablative field from the electrode is ellipsoid in shape, ideally it should match the shape and orientation of the adrenal tumour in an attempt to achieve complete ablation in a single cycle (Figure 8). Ideally, the Cool-Tip™ electrode should be placed along the long axis of the tumour, while the LeVeen™ electrode should be placed perpendicular to its long axis. Selecting a safe path for electrode insertion is much more important, which means that achieving complete ablation in more than one cycle may be unavoidable.

Risk of Hypertensive Crisis

The potential risk of a life-threatening hypertensive crisis is attributed to direct stimulation of the adrenal gland by the heat energy. Typically, during open and laparoscopic adrenalectomy, the adrenal vein is ligated, which limits the risk. By contrast, it is not ligated during percutaneous RFA. There is therefore a chance of sudden release of catecholamines into the systemic circulation resulting in a hypertensive crisis even after ablating normal adrenal tissue.[15-17] One patient in our series who had multiple medical conditions developed a hypertensive crisis, which presumably precipitated an acute coronary syndrome. It is important to ensure that the blood pressures of patients undergoing this procedure are all adequately controlled. Apart from blood pressure, the heart rate, electrocardiogram, and oxygen saturation should also be closely monitored throughout the procedure; and alpha- and beta-receptor blocking drugs must be readily available in case a crisis occurs.

Overall, the safety of this procedure relies on careful and skilled placement of the needle electrode into the adrenal tumour. This requires the services of an experienced and well-trained interventional radiologist, and preparedness for a hypertensive crisis.

CONCLUSION

No major morbidity or mortality was encountered in the current series, apart from one hypertensive crisis, which presumably lead to the patient's acute coronary syndrome. Although CT-guided RFA of adrenal tumours can be technically challenging for small or unfavourably positioned lesions, compared to current results associated with standard open or laparoscopic surgery, it can be considered a safer procedure in experienced hands.

DECLARATION

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