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Modified technique of cavoatrial tumor thrombectomy without cardiopulmonary by-pass and hypothermic circulatory arrest: a preliminary report

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Introduction Traditionally, tumor thrombi extending into the right atrium have been managed by open surgery with sternotomy, cardiopulmonary bypass circulation and hypothermic circulatory arrest, and are associated with significant morbidity and mortality rates. Here, we evaluate the results of cavoatrial thrombectomy using our own, Foley catheter assisted-technique, obviating the need for thoracotomy, extracorporeal circulation, and/or hypothermic circulatory arrest.

Material and methods Between June 2013 and January 2015, 4 consecutive patients underwent cavoatrial thrombectomy performed with our own, Foley catheter assisted technique, *via* Chevron incision, with no need for extracorporeal circulation or hypothermy for renal cell carcinoma with tumor thrombus extending into the right atrium. Analyses of patients' data from a prospectively maintained database with respect to perioperative characteristics, morbidity and mortality were performed.

Results The total mean duration of surgery was 255 minutes. The mean time of total IVC (inferior vena cava) occlusion was 90 seconds. The average blood loss volume, timed from the beginning of cavotomy incision until its closure, was 1200 ml. The total mean intraoperative blood loss was 3,150 ml. There was no perioperative death. Postoperative complications included one transient acute kidney injury requiring one-off hemodialysis and one re-operation due to bleeding. The follow-up time ranged between 12 to 17 months. None of the patients developed disease recurrence. All patients were still alive at the time of study completion.

Conclusions Obtained results support the validity of our own, Foley catheter assisted technique, without cardiopulmonary bypass and hypothermic circulatory arrest for the treatment of renal cell carcinoma with tumor thrombus extending into the right atrium.

Key Words: cavoatrial thrombectomy ‹› renal cell carcinoma ‹› complications

INTRODUCTION

Treatment of the cavoatrial tumor thrombus (TT) remains extremely challenging, even for a well-experienced surgeon, not only due to the technical difficulties that it possesses, but also because of the very high associated risks of perioperative complications and mortality (47% and 15%, respectively) [1, 2]. The presence of TT within the circulatory system can compromise venous return from the lower half of the body causing blood stasis, development of by-pass circulation, neovascularisation, and further thromboembolic complications [3, 4, 5]. If left untreated, TT can further cause massive pulmonary emboli, tricuspid valve obstruction, or Budd-Chiari syndrome [6]. The standard surgical management offered to patients with renal cell carcinoma (RCC) with concomitant cavoatrial TT

involves median sternotomy and extracorporeal circulation [7, 8].
Herein, we present the results of cavoatrial TT treatment in the RCC patients using our own, Foley catheter assisted technique, obviating the need for thoracotomy, extracorporeal circulation, and/or hypothermic circulatory arrest.

MATERIAL AND METHODS

Patient cohort

Between June 2013 and January 2015, four patients diagnosed in our institution with RCC and cavoatrial TT underwent radical (n = 3), or cytoreductive (n = 1) nephrectomy with thrombectomy performed with our own, Foley catheter – assisted technique, *via* Chevron incision, with no need for extracorporeal circulation or hypothermy [9]. The extent of the TT was preoperatively evaluated using contrast-enhanced multiphasic computed tomography, as well as the transoesophageal echocardiography (TOE), and was classified as level IV as per the Neves and Zincke classification system in all cases [10]. Patient's performance status was assessed according to the Eastern Cooperative Oncology Group (ECOG) [11] and scored 1 in all studied cases. One man was diagnosed with a single metastasis to the left adrenal. All patients underwent anatomical and functional preoperative assessment of their cardiovascular system, as well as their lungs and kidneys. Intraoperative positioning of the TT was closely monitored under TOE guidance throughout Foley catheter balloon assisted cavoatrial TT re-traction towards the cavotomy located at the level of the ostium of the renal vein supplying the affected kidney.

Technique

Cavoatrial tumor thrombectomy was performed as described previously [9]. Briefly, after laparotomy *via* Chevron incision had been carried out, exposing the infra- and suprarenal (up to the level of the heart) parts of the inferior vena cava (IVC) (with liver mobilisation), as well as, both renal veins and

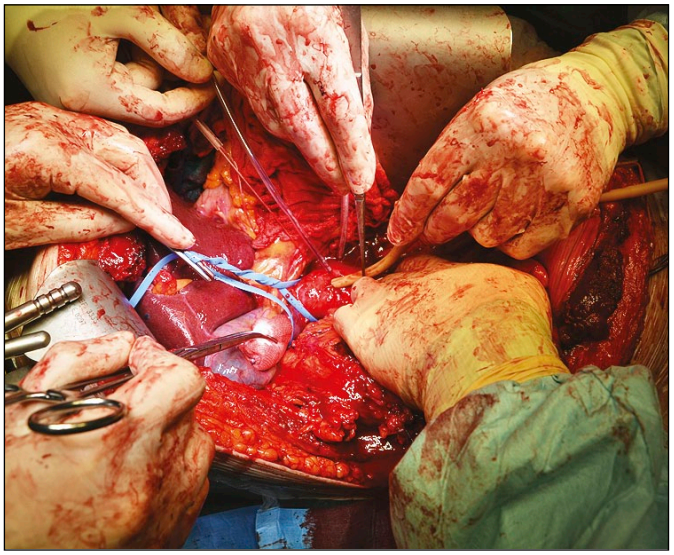

Figure 1. *Capture from the cavotomy and Foley catheter insertion into the IVC. Visible Rummel tourniquet loosely tightened over the left renal vein and the hepatic porta (white), as well as over the IVC just above the renal veins (blue). Tourniquet over the infrarenal portion of the IVC has been obstructed with the operator's hand while performing Foley catheter insertion.*

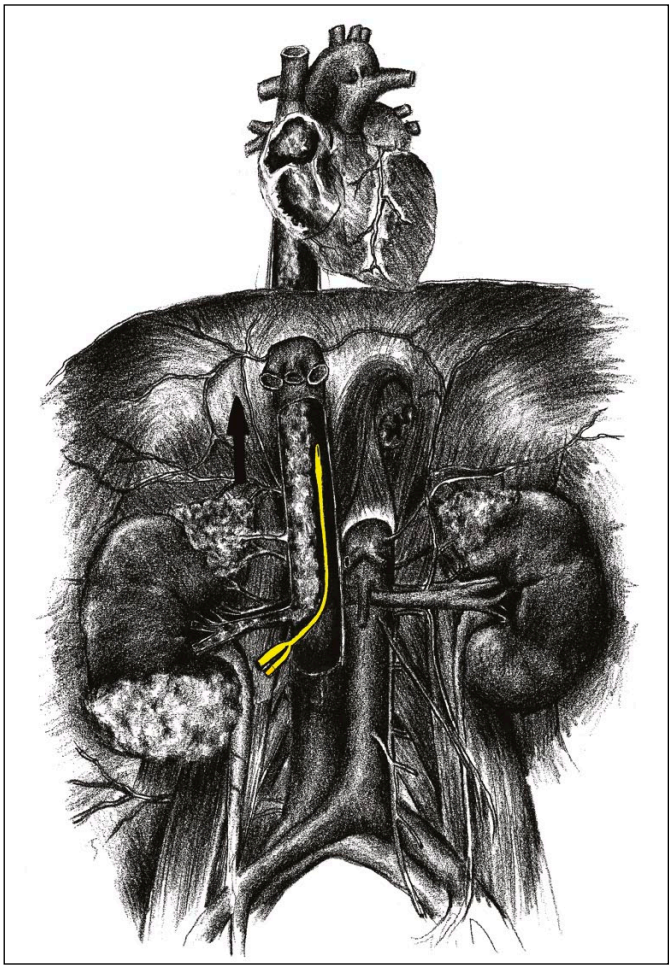

Figure 2. *Schematic view of Foley catheter balloon-assisted cavoatrial thrombectomy.*
The left renal vein, the infrarenal inferior vena cava and the hepatic porta are encircled with the Rummel tourniquets. Tumor thrombus extends through the inferior vena cava into the right atrium. The catheter is being inserted into the inferior vena cava up to the right atrium above tumor thrombus. Arrow indicates the direction of the Foley catheter insertion.

the infrarenal aorta, the renal artery, supplying the kidney with the tumor, was ligated. In order to prevent TT fragmentation and subsequent thromboembolic complications, Rummel tourniquets were loosely placed over the infrarenal IVC, the contralateral renal vein, and the hepatic porta, while the diseased kidney was fully mobilized being attached only to the renal vein. A purse string suture was stitched over the IVC where the cavotomy was performed. Next, the intraoperative hemodynamic reserve was assessed by placing the patient in the Trendelenburg position while clamping the IVC for one minute. The aim of this maneuver was to ascertain whether blood transfusion or circulatory support would be required, which, fortunately, was not the case in any of our patients. The infrarenal IVC, the unaffected renal vein and possibly the hepatic porta (only in case of significant hemorrhage), were clamped with tourniquets. A short, 2 cm long, cavotomy incision

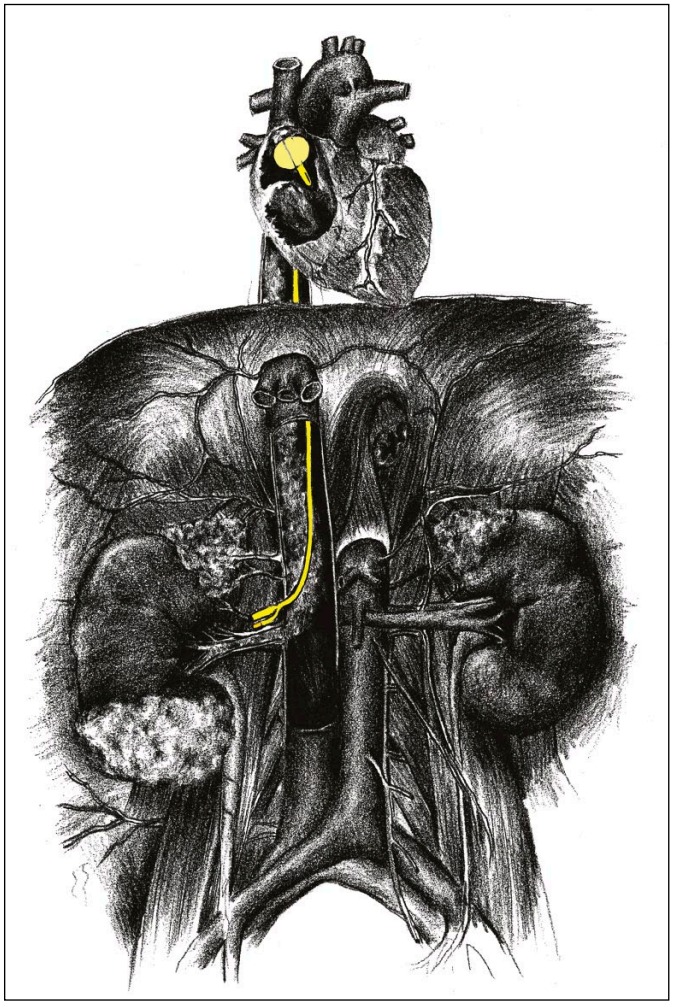

Figure 3. *Schematic view of Foley catheter balloon-assisted cavoatrial thrombectomy. Foley catheter with inflated balloon just above the tumor thrombus within the right atrium.*

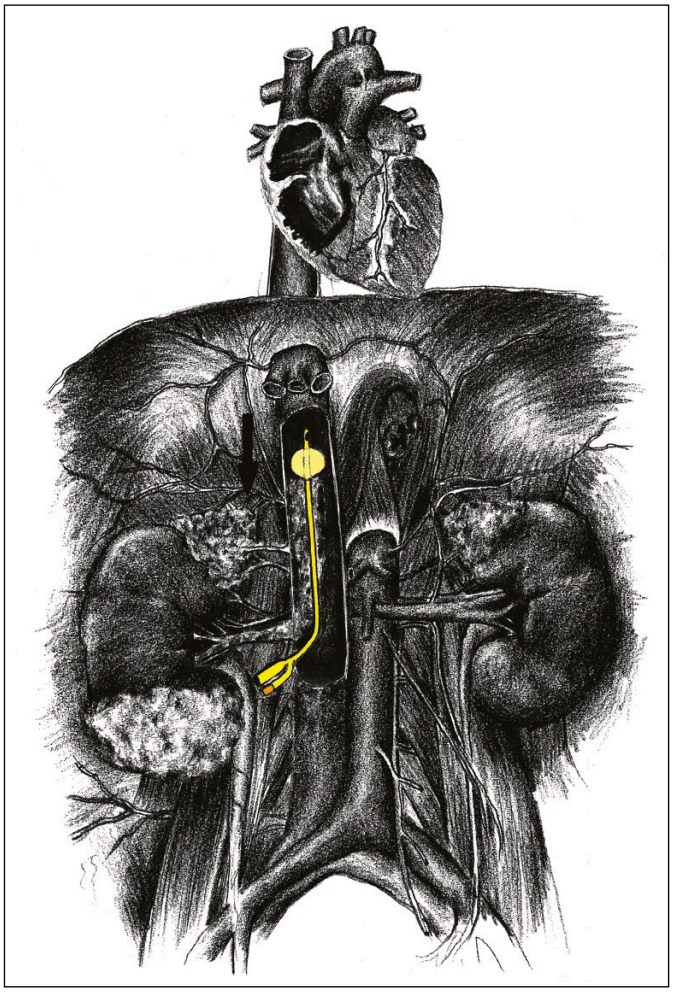

Figure 4. *Schematic view of Foley catheter balloon-assisted cavoatrial thrombectomy. Tumor thrombus being retracted from the right atrium with inflated baloon of Foley catheter. Arrow indicates the direction of the Foley catheter and thrombus withdrawal.*

was performed at the level of the renal vein ostium on the affected side, where a 22F Foley catheter (siliconised 2-way catheter, maximum inflatable volume of the balloon of 30 ml, Unomedical, Sdn. Bhd., Denmark) was carefully introduced and passed through, up to the right atrium under direct TOE guidance (Figures 1 and 2). As soon as the catheter reached the target position (just above the TT), the catheter balloon was inflated with approximately 15 ml of normal saline (Figure 3), and the TT was removed by slowly withdrawing the catheter (constantly adjusting balloon volume to the IVC diameter under continuous TOE guidance) allowing for *en bloc* TT with the tumorous kidney removal (Figure 4). The cavotomy was closed with a double-running suture (4-0 prolene). After a meticulous haemostasis was achieved, two surgical drains were left *in situ* (one

within the renal bed and the second within the peritoneal cavity), and the laparotomy incision was closed in layers.

RESULTS

Patients' clinical and histological tumor characteristics have been presented in Table 1. Three patients underwent radical and one had cytoreductive nephrectomy with complete re-traction of the TT from the IVC and the right atrium with Foley catheter, but no median sternotomy, extracorporeal circulation or hypothermy were required. The total mean duration of surgery was 255 minutes. The mean time of total IVC occlusion was 90 seconds. It took approximately 15 seconds to insert a Foley catheter into the right atrium and to expand the balloon of the catheter above the thrombus. The average blood loss volume, timed from the beginning of cavotomy incision until its closure, was 1200 ml. The initial 200–300 ml blood loss occurred during Foley catheter insertion into the right atrium, whereas, the TT retraction was associated with minimal blood loss of merely 50 ml on average. The total mean intraoperative blood loss was 3,150 ml. The mean number of units of blood needed during the surgery was 6. There was no immediate or 30-day perioperative death. Intraoperative real time TOE did not detect any TT fragmentation or pulmonary emboli in any of the operated cases. Two patients developed postoperative complications: one had transient acute kidney injury requiring one-off hemodialysis; the other patient required re-operation shortly after the surgery (within the first 24 hours) due to a leaking diaphragmatic blood vessel. Table 2 gives surgical characteristics of patients with RCC and right atrial tumor thrombus treated with radical or cytoreductive nephrectomy and cavoatrial thrombectomy using a Foley catheter assisted technique.

The mean hospital stay was 16.25 days. In all patients, histology showed clear cell RCC and one patient had additional sarcomatoid features detected. All tumors were staged pT3c. Two cases were graded as Fuhrman 3, one as Fuhrman 2, and one as Fuhrman 4. The follow-up time ranged between 12 and 17 months. None of the patients developed disease recurrence. All patients were still alive at the time of study completion.

DISCUSSION

Despite its rarity, renal cell carcinoma infiltrating venous system up to the level of the right atrium poses a significant therapeutic challenge [12, 13]. The standard treatment of this rare entity involves

Table 1. *Patients' clinical and histological tumor characteristics*

N	Sex	Age (years)	Side	Tumor size (cm)	Histology	Fuhrman	pTNM
1	M	75	R	8.4 x 9.0	Carcinoma clarocellulare	2	T3cNxMx
2	M	54	R	12.0 x 7.0	Carcinoma clarocellulare partim sarcomatoides	4	T3cNxMx
3	M	56	R	12.0 x 10.0	Carcinoma clarocellulare	3	T3cNxMx
4	M	68	L	8.0 x 8.5	Carcinoma clarocellulare	3	T3cN0M1

N – number, M – man; R – right, L — left, T – tumor, N – regional lymph nodes; M – metastases

Table 2. *Surgical characteristics of patients with RCC (renal cell carcinoma) and atrial tumor thrombus treated with radical or cytoreductive nephrectomy and cavoatrial thrombectomy using Foley catheter assisted technique*

Variable	Value
Mean duration of surgery ±SD (min)	255 ±41
Mean time of the IVC occlusion ±SD (min)	90 ±35
Mean blood loss during TT thrombectomy ±SD (min)	1,200 ±200
Mean intraoperative blood loss ±SD (ml)	2,185 ±284
Mean perioperative blood loss ±SD (ml)	3,150 ±1,543
Mean intraoperative red blood cells transfusion ±SD (units)	6 ±2.3
Mean perioperative red blood cells transfusion ±SD (units)	16 ±12.6
Mean length of hospital stay ±SD (days)	16.25 ±4.9

SD – standard deviation, IVC – inferior vena cava, min – minutes, ml – milliliters

radical nephrectomy with concurrent thrombectomy, median sternotomy, atriotomy, and extracorporeal circulation with or without hypothermic circulatory arrest (providing patient is fit for surgery) [7, 8]. Despite its curative potential, this therapeutic approach is associated with long surgery duration, thereby potentially significant blood loss, as well as a high risk of perioperative complications and mortality [12, 14]. Moreover, these patients need to be heparinized during the surgery, which, if associated with platelet dysfunction, can subsequently result in profound coagulopathy and massive uncontrollable hemorrhage [15]. Hypothermic circulatory arrest, in turn, can cause transient or permanent neurological dysfunction, such as hallucinations or stroke [16]. One can minimize the risk of these major complications by clamping the descending aorta just above the diaphragm. This particular maneuver mandates, however, median sternotomy, extracorporeal circulation and the posterior mediastinal access, which itself carries the risk of injury to the oesophagus and/or the vagus [17]. Skinner et al. [7] proposed a manual evacuation of the tumor thrombus (TT) *via* a small incision in the right atrium. This approach, however, is associated with high intraoperative risk of TT fragmentation with subsequent pulmonary emboli.

The standard balloon assisted operative techniques to retract the TT from the inferior vena cava, or to cause IVC occlusion and thereby facilitate bloodless operative field, have been widely in use. These, however, require extracorporeal circulation, hypothermic circulatory arrest, or were solely reserved for the treatment of TT not extending into the right atrium [18-24]. Similarly, Yanaga et al. [25] have described their own technique of TT retraction from the right atrium *via* balloon assisted 12F aortic catheter, which also required extracorporeal circulation.

Our own technique for TT retraction from the right atrium is relatively easy. It requires a Foley catheter with its balloon inflated while within the right atrium constantly under TOE guidance. Hence, thoracotomy, median sternotomy, extracorporeal circulation or hypothermic circulatory arrest, are not necessary. Although we found this approach to be very effective, our method cannot be routinely used without caveats – it is not applicable in cases of direct IVC wall infiltration by the TT, or in cases when the TT extends into the right ventricle. Of note, this technique is not without risks such as failure of TT retraction from the right atrium, TT fragmentation with subsequent pulmonary emboli, or incomplete evacuation of the TT. Moreover, intraoperative irritation of the right atrium with the catheter can result in fatal arrhythmias [26]. The ideal candidate for a cavoatrial thrombectomy using Foley catheter assisted technique, without need for thoracotomy, extracorporeal circulation, and/or hypothermic circulatory arrest is a patient in whom a preoperative CT excluded direct wall invasion of the IVC and/or its branching veins (i.e. hepatic veins) by the TT. Otherwise, cavoatrial thrombectomy could risk thrombus fragmentation and its incomplete evacuation. The so-called "inverted icicle" thrombus morphology can allow its removal *via* the described approach. The ultimate decision for the operative technique depends on intraoperative TOE findings with regards to TT level, its size, shape and movement on respiration, as well as its mobility in relation to the venous wall and the atrium. The relative contraindications to the use of the described technique are: thrombus extending over 3 cm into the right atrium, and/or no TT mobility on respiration (complete IVC obstruction or IVC wall invasion).

Although we did not observe any of the aforementioned complications, these risks exist and one must be aware of them. In each case, therefore, we used real time TOE guidance throughout the entire procedure. From our experience, the intraoperative TOE guidance is mandatory for a safe and successful surgery outcome. Moreover, to further enhance the patient's safety and to minimize the risks of failure or complications, our patients were closely monitored hemodynamically throughout the operation. Additionally, our operating team always included an experienced cardiothoracic surgeon, who was on standby should extracorporeal circulatory support be rendered necessary to use. This team back-up allows for possible intraoperative pulmonary embolus removal in case of unintentional TT fragmentation. Should this be the case, the real-time intraoperative TOE guidance enables prompt diagnosis and the imminent decision about commencement of the extracorporeal circulation with pulmonary embolectomy can be made.

In the present series, we observed substantial total mean intraoperative blood loss (3,150 ml). It was attributed to collateral veins around the kidney and occurred predominantly before cavotomy and tumor thrombus retrieval. The average blood loss volume, timed from the beginning of cavotomy incision until its closure, was 1,200 ml. The initial 200-300 ml blood loss occurred during Foley catheter insertion into the right atrium, whereas, TT retraction was associated with minimal blood loss of merely 50 ml on average. Blood loss of 850-950 ml occurred during cavotomy closure and was attributed mainly to the lumbar veins. In addition, the hepatic veins contributed to the bleeding as we placed the Rummel tourniquet

loosely over the hepatic porta in order to prevent TT fragmentation and subsequent thromboembolic complications. In our study, the mean number of units of blood needed during the surgery was 6. Although considerable, our total mean operative blood loss is comparable with or better than the blood loss and transfusion requirements reported in other studies which analyzed surgical outcomes after conventional or minimally invasive interventions for level III or IV TT [22, 25, 27, 28]. In their series, Radak et al. [27] presented the perioperative outcomes of five radical nephrectomies with atrial thrombectomy with the use of a normothermic cardiopulmonary bypass. Although they did not report the mean blood loss, the average number of packed cells transfusions was 12. A recent multicenter study, which retrospectively analyzed the perioperative outcomes of 162 surgical resection of RCC with inferior vena cava TT extending above the hepatic veins, reported the median estimated blood loss of 3,000 ml [12]. In another contemporary series, an atrial thrombectomy was associated with the mean transfusion of 13.8 units of packed red blood cells [28]. The mean blood loss reported for thrombectomies for level III or IV TT performed without sternotomy and cardiopulmonary bypass was between 2,500–3,730 ml [22, 25].

In our study, one man was diagnosed with a single metastasis to the left adrenal gland. He underwent cytoreductive nephrectomy with atrial thrombectomy. However, performing cytoreductive nephrectomy with thrombectomy is controversial. Several research studies reported conflicting results regarding survival rates in patients with RCC invading the inferior vena cava and distant metastases. In their study, Staehler at al. [29] observed a very low survival rate after cytoreductive nephrectomy with thrombectomy (the actuarial 2-year survival rate for patients with distant metastasis was 26%, whereas the 5-year survival rate of all patients without distant metastasis was 34%). However, a study by Zini et al. [30] reported better disease specific survival rates in patients with metastatic RCC who underwent cytoreductive nephrectomy with inferior vena cava thrombectomy (the 2- and 5-year disease specific survival rates were 43% and 21%, respectively). Further data supporting cytoreductive nephrectomy with thrombectomy in metastatic RCC comes from the report by Parekh et al. [31] who observed a 3-year cancer related mortality of 22% in patients without synchronous metastases, and 38% in patients with synchronous metastases.

CONCLUSIONS

Our technique of radical and cytoreductive nephrectomy with extended thrombectomy using a Foley catheter, *via* Chevron incision but with no extracorporeal circulation and hypothermic circulatory arrest, under constant TOE guidance, proved to be safe and effective.

The intraoperative TOE guidance is necessary for the safe and successful balloon inflation within the right atrium just above the TT.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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