Radial artery occlusion after transradial coronary catheterization

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Abstract: The transradial approach (TRA) for coronary angiography and interventions is increasingly utilized around the world. Radial artery occlusion (RAO) is the most common significant complication after transradial catheterization, with incidence varying between 1% and 10%. Although RAO is rarely accompanied by hand ischemia, it is an important complication because it prohibits future transradial access and radial artery utilization as a conduit for coronary artery bypass grafting or arteriovenous fistula formation. In this review, we discuss factors predicting the occurrence of RAO, aspects of accurate and prompt recognition, methods that contribute to its prevention and possible treatment options.

Keywords: Radial approach; radial artery occlusion (RAO); hemostasis

Introduction

Following the introduction of transradial coronary angiography by Campeau *et al.* in 1989 (1), Kiemeneij *et al.* were the first to document coronary angioplasty and stenting via the transradial approach (TRA) in 1993 (2). While the transfemoral approach (TFA) remains the most common method for coronary angiography and interventions, an increasing number of interventional cardiologists are performing percutaneous interventions through the radial artery (3-6). Furthermore, multiple studies have demonstrated significant benefit with TRA, due to its relatively lower potential for access site bleeding and high patient comfort/satisfaction, while maintaining an overall high procedural success rate (7-15). However, the increasing operators experience on TRA is followed by decreased experience in TFA, leading to more access site complications when this access site is chosen, the so called "Campeau Radial Paradox" (16).

Radial artery occlusion (RAO)

In the majority of cases performed through TRA, access site complications are predictable and easy to treat (17). New complications associated with TRA, like forearm pain or upper extremity loss of strength are under further evaluation in order to evaluate their impact on patients function and quality of life (18). However, treatment of complications after TRA depends on the experience of the interventional cardiologist performing the procedure. Potential access site complications during percutaneous procedures performed with a TRA are summarized in *Table 1*.

Pathogenesis of RAO

The most common complication of TRA is RAO, which occurs in about 1–10% of cases (19-22). Endothelial injury of the radial artery and decrease in blood flow after sheath and catheter insertion appear to contribute to thrombus

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Table 1 Potential access site complications during percutaneous procedures performed via a transradial approach

RAO
Radial artery spasm
Persistent postprocedural pain
Upper extremity loss of strength
Hematoma [EASY trial (15) classification]
Pseudoaneurysm
Arteriovenous fistula formation
Radial artery perforation
Radial artery eversion during sheath removal
Hand ischemia
Compartment syndrome

EASY, early discharge after transradial stenting of coronary arteries; RAO, radial artery occlusion.

formation and are predisposing factors for RAO (18,19,23). In addition, repeated radial artery cannulation can promote intimal hyperplasia and increased intima-media thickness (22,24,25), resulting in negative remodeling of the arterial wall and further predisposition to RAO (26). Radial artery stenosis has been shown to occur in 31% of patients within 2 days after TRA and in 28% late after the procedure (23). Imaging studies, such as vascular ultrasound (27), angiography (28), optical coherence tomography (24) and histopathological examination of materials aspirated after mechanical recanalization of occluded radial arteries (29) support this thrombus formation theory.

In most cases RAO occurs promptly after the procedure and up to 50% of patients have spontaneous recanalization of the artery within 1–3 months (22,30). Stella *et al.* found a 5.3% rate of RAO at the time of hospital discharge in a study of 563 patients who underwent transradial artery coronary angioplasty (20). RAO is, in the majority of patients, asymptomatic. This is due to dual blood supply of the hand and the usually rich network of collateral circulation: the radial and ulnar arteries undergo multiple anastomoses before they are connected in the hand by the superficial and deep palmar arches. Thus, if the radial artery is occluded, blood supply of the hand can be maintained by the ulnar collateral circulation and RAO is a quiescent event. However, cases of hand ischemia after RAO have been described in the setting of inadequate collateral circulation (31-33). Some patients may experience pain

at the site of the occlusion, paresthesias or reduced limb function (23).

Eligibility for TRA

Traditionally, assessment of dual hand circulation to assess eligibility for transradial access is performed by the modified Allen's test: while occlusive pressure to both the ulnar and the radial arteries is applied by the examiner's fingers, the patient clenches their first for about one minute; the hand is then relaxed and pressure on the ulnar artery is released. Positive modified Allen's test is recorded when the color of the hand is regained within 5–10 seconds, indicating adequate collateral circulation. These patients were traditionally considered as good candidates for TRA. However, new data makes us reconsider the use of this practice. We recently showed that TRA for coronary angiography and ad hoc angioplasty can be performed with similar efficacy and safety regardless of the preprocedural Allen's test result (34). Barbeau's test (35) is an alternative method for evaluating collateral circulation of the hand and is more objective compared with modified Allen's test: a pulse oximeter is placed on the ipsilateral thumb and the morphology of the plethysmography tracing is examined after occlusion of the radial artery. Changes of the tracing are observed and categorized into four types. In type 4 there is absence of plethysmographic waveform indicating inadequate collateral circulation. However, neither modified Allen's test, nor Barbeau's test have been shown to predict clinically significant complications after TRA, making their value in clinical practice controversial (36). The most reliable method for assessing the collateral circulation before obtaining angiographic access is duplex ultrasonography (19). With this method the examiner can evaluate the blood flow in the arteries and collaterals and better understand their anatomy.

Diagnosis of RAO

Absence of radial pulse after TRA procedures may be a strong indicator of RAO. However, a palpable pulse does not exclude the diagnosis of RAO: collateral blood flow, through mainly the anterior interosseous artery, may supply the periphery of the radial artery distally to the occlusion, giving a false impression of radial artery patency. Therefore, RAO can often go undiagnosed, and its true prevalence may be underestimated. Radial artery

patency is better evaluated with clinical testing as the reverse Barbeau's test and with Doppler ultrasonography. In the former method, the ulnar artery is occluded and a pulse oximeter is placed on the ipsilateral thumb. Absence of plethysmographic waveforms is indicative of RAO. The latter method provides structural imaging of the arteries and assessment of blood flow with color Doppler ultrasound. Absence of flow in the radial artery suggests occlusion. The laser Doppler scan is a novel noninvasive method that may allow quick diagnosis of RAO (37).

Why is it important to maintain radial artery patency?

Many authors emphasize the importance of maintaining radial artery patency after TRA (18,19,38). A patent radial artery may be re-cannulated for future coronary artery procedures, used as conduit for coronary artery bypass grafting, arteriovenous fistula formation for hemodialysis in patients with end stage renal disease, or for intra-arterial pressure monitoring. Prior RAO has also been regarded as a contraindication for ipsilateral transulnar approach. However, Kedev et al. recently showed that transulnar approach can be safely performed by experienced operators even in patients with prior ipsilateral RAO (39). Agostoni et al. have also reported 6 cases of simultaneous radial and ipsilateral ulnar artery cannulation without any complications (40). A recently published consensus on TRA underlines the need of radial artery patency evaluation before discharge, as well as during the initial post-procedure follow-up visit (41).

Factors predisposing to RAO

Patient's baseline characteristics and RAO

Many studies have evaluated baseline patient characteristics as predictors for RAO. Sex, age, diabetes, statin use, body weight, serum creatinine, and smoking have been evaluated; however, results are not consistent across all studies. *Table 2* shows how these factors are associated with the incidence of RAO in present literature.

Procedural characteristics

In addition to clinical characteristics, procedural factors can predict and influence RAO incidence. Sheath size and its relation to radial artery diameter, as well as the utilization of specific pharmacological agents (such as anticoagulants and vasodilators) have been studied.

Sheath size and its relation to radial artery diameter

Bigger sheath sizes can lead to vascular damage and create a pro-thrombotic environment. Yoo et al. (54) found that the mean radial artery inner diameter was 2.69±0.40 mm in men and 2.43±0.38 mm in women. Given that the outer diameter of a 6F sheath is 2.52 mm, 32% of men and 60% of women in that study had radial artery diameter smaller than the outer diameter of a 6F sheath. In a Japanese study (30) the proportion of serious blood flow reduction in the radial artery was 13% when the outer sheath diameter was bigger than the inner artery diameter and 4% when the sheath diameter was smaller (P=0.01). Uhlemann et al. (44) found that the incidence of RAO was 13.7% in patients managed with 5F system compared with 30.5% in the group of 6F system (P<0.001). Other studies (55) have shown similar conclusions, underlining the importance of preserving a sheath-to-artery diameter ratio <1. In the Novel Angioplasty Using Coronary Accessor Trial (NAUSICA) patients were randomly assigned in a 1:1 ratio to undergo either 4F [using the KIWAMI, Heartrail II guide (Terumo, Tokyo, Japan), with an outer diameter of 1.43 mm] or 6F system (56). The primary endpoint was RAO at the next day of the procedure, defined as the absence of radial pulse confirmed by a negative reverse Allen's test. Although the RAO rate was lower in the 4F versus the 6F groups, the difference was not statistically significant (0% *vs.* 4%, P=0.08). However, overall access site-related complications were significant lower in the 4F group (0% *vs.* 6%, P=0.02). Polimeni et al. (57) have recently published a meta-analysis of 11 studies (3 randomized and 8 nonrandomized) comparing the clinical and procedural outcomes of 5F versus 6F sheaths in transradial coronary interventions. They found no statistically significant difference in RAO incidence between the two groups [OR =0.88 (0.50–1.56), P=0.67]. Interestingly, in the meta-regression analysis on the influence of female sex on RAO, there was an increasing benefit with 5F sheath as the percentage of women included into the study increased (P=0.02).

Material miniaturization to prevent RAO

Despite the fact that the radial artery wall has elastic properties and can be stretched (19), the outer diameter of the sheath should be, whenever possible, smaller than

Table 2 Studies examining the effect of baseline patient characteristics on the incidence of RAO

RAO predictors	Trials	Results		
		RAO	No RAO	P
Age (years)	Pancholy et al. (42)	73.3±12.4	65.3±12.6	<0.05
	Lee et al. (43)	56.00±17.6	65.7±10.4	0.032
	Uhlemann et al. (44)	OR (1 year age increase) 0.973 (0.954–0.992)		0.005
Female gender	Aykan et al. (45)	OR 66.135 (4.584–954.131)		0.002
	Pancholy et al. (42)	12.9%	87.1%	<0.05
	Lisowska et al. (46)	13/33	40/187	0.025
	Ruhnau et al. (47)	67%	40%	0.03
	Tuncez et al. (48)	80%	54%	0.02
	Uhleman et al. (44)	OR 2.110 (1.370–3.247)		0.001
Body weight (kg)	Pancholy et al. (42)	68.6±15.7	88.6±20.3	<0.05
	Plante et al. (49)	OR (<84 kg) 2.78 (1.08–8.00)		0.032
	Tuncez et al. (48) (<80 kg)	80%	42%	0.01
	Levin et al. (50)	78±11	89±13	0.031
	Dangoisse et al. (51)	≤70 kg had lower 24 h radial artery patency		0.02
Statin use	Honda et al. (52)	OR 0.50 (0.255–0.985)		<0.05
Serum creatinine (µmol/L)	Lisowska et al. (46)	76.9±21.2	130.8±53.0	0.04
Peripheral artery disease	Dangoisse et al. (51)	24 h lower radial artery patency		0.007
	Uhlemann et al. (44)	OR 1.986 (1.042–3.783)		0.037
Diabetes	Nagai et al. (22)	No radial artery flow		0.05
Smoking	Cubero et al. (53)	Present or ex-smokers		<0.04

RAO, radial artery occlusion.

the radial artery diameter during transradial procedures. Maintaining a sheath-to-artery ratio <1 is an essential factor in preventing RAO. Therefore, small size sheaths should be used for diagnostic angiography and for many non-complex coronary interventions, especially in women who have lower mean radial artery diameter compared to men. Hydrophilic sheaths may also reduce the risk of RAO (41). Sheathless guide catheters can reduce the outer diameter of vascular access system by 1–2 Fr compared with conventional sheaths and catheters (58,59). Yoshimachi et al. (60) studied the safety and feasibility of the new 5F Glidesheath Slender (Terumo), a hydrophilic coated introducer sheath, which has an inner diameter compatible with a conventional 5F guiding catheter, while the outer diameter is similar to that

of a conventional 4F sheath. None of the 21 patients in the study experienced RAO.

Anticoagulation

In line with the thrombus formation theory of RAO, anticoagulant agents have been investigated as a means to reduce its incidence. Spaulding et al. (61) in a non-randomized study diagnosed RAO in 71% of patients who did not receive heparin, 24% of patients who received 2000–3,000 IU of heparin and 4.3% of patients who received 5,000 IU of heparin (P<0.05). Bernat et al. (62) studied the incidence of RAO in patients treated with either 2,000 or 5,000 IU of unfractionated heparin. Lower dose of heparin

was associated with numerically double rates of RAO (5.9% vs. 2.9%, P=0.17). In the same study, when patients with RAO were treated with compression of the ipsilateral ulnar artery for 60 minutes, the incidence of RAO was reduced from 5.9% to 4.1% in the low-dose heparin group and from 2.9% to 0.8% in the high-dose heparin group (P=0.03). It has been suggested that heparin can be delivered either intravenously or via the arterial sheath having the same efficacy on reducing the incidence of RAO (63). Other anticoagulant agents that have been studied are enoxaparin (64) and bivalirudin (49,65). Plante et al. (49) compared bivalirudin versus heparin on RAO after transradial catheterization. In patients requiring angioplasty they administered a bolus 0.75 mg/kg of bivalirudin, followed by an infusion at a rate of 1.75 mg/kg/h. Patients who underwent only coronary angiography without angioplasty were given a bolus of 70 IU/kg of unfractionated heparin instead. They found no significant difference on the occurrence of RAO 4–8 weeks after the procedure (3.5% bivalirudin vs. 7.0% heparin, P=0.18). Hahalis et al. (66) randomized 308 consecutive patients undergoing transradial coronary angiography with 5F catheters to receive 2,500 or 5,000 IU of unfractionated heparin. The frequency of RAO between the two groups was similar (15.9% with low heparin dose vs. 14% with standard heparin dose, P=0.7). A case-control study by Pancholy et al. (67) compared patients receiving chronic oral anticoagulation with warfarin who underwent transradial coronary angiography without parenteral anticoagulation with non-warfarinized patients who received an intravenous heparin bolus (50 IU/kg). Patients under warfarin had a higher incidence of early (24 hours) and late (30 days) RAO compared with the heparin group (18.6% vs. 9.6%, P=0.024 and 13.9% vs. 5.2%, P=0.01, respectively). In a recently published systematic review and meta-analysis (68) it was found that the most significant measure that decreased RAO was higher doses of heparin (risk ratio 0.36, 95% CI: 0.17–0.76). The recommended dose of unfractionated heparin is at least 50 IU/kg, up to 5,000 IU (41). Bivalirudin should be administered at a dose of 0.75 mg/kg bolus intravenously for diagnostic procedures, followed by infusion at 1.75 mg/kg/h if PCI is indicated (41). Enoxaparin, at a 60 mg dose (41), can be also used via the arterial sheath.

Vasodilators and RAO

Many vasodilator agents have been used during TRA for prevention of radial artery spasm and RAO, including nitrates, calcium channel blockers, lidocaine, magnesium sulphate and alpha blockers. Increase of peri-procedural radial artery diameter was demonstrated in a series of studies (69-72). Dharma et al. (73) found that the use of post-procedural/pre-hemostasis intra-arterial nitroglycerin reduced the incidence of RAO compared with placebo (8.3% vs. 11.7%, P=0.006). A systematic review by Kwok et al. (74) analyzed the rate of radial artery spasm in 22 clinical studies. They concluded that 5 mg of verapamil or verapamil in combination with nitroglycerin are the most effective measures to prevent radial artery spasm. However, in a study by Izgi et al. (75), none of 15 consecutive patients who were treated with TRA without vasodilators experienced RAO. Further investigation is needed to elucidate the optimal use of vasodilator regimens for the prevention of RAO. Table 3 summarizes the effect of procedural characteristics on the incidence of RAO in current literature.

Post-procedural care

Patent hemostasis

The term "patent hemostasis" is used to describe patency of the radial artery while hemostasis at the site of puncture is achieved with a hemostatic device. This non-occlusive compression of the radial artery has been recognized as an independent predictor of radial artery patency after TRA. In the Prevention of Radial Artery Occlusion-Patent Hemostasis Evaluation Trial (PROPHET), 436 consecutive patients undergoing transradial catheterization were randomized between conventional hemostasis and patent hemostasis (42). Radial artery patency, assessed using the reverse Barbeau's test, was evaluated at 24 hours and 1 month after the procedure. There was a significant reduction of 24 hours RAO (5% vs. 12%, P<0.05) and 1 month RAO (1.8% vs. 7%, P<0.05) in the patent hemostasis group compared with the conventional hemostasis group. The Radial Compression Guided by Mean Artery Pressure Versus standard Compression with a Pneumatic Device (RACOMAP) trial has also shown the importance of patent hemostasis (53). In this trial, patients who received compression guided by mean arterial pressure had significant reduction of RAO incidence compared with patients who received a standard compression with 15 cc of air in the bladder of the TR Band device (Terumo, Somerset, NJ, USA) (1.2% vs. 12%, P=0.0001). In a recently published study (88), patients managed with standard compression of the radial artery for 2 hours using a TR Band device (the air bladder of the device was filled initially with 18 mL of air, then

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Table 3 Studies examining the effect of procedural characteristics on the incidence of RAO

Trials	Strategies evaluated	Time of RAO evaluation after TRA	Results	P
Trials evaluating different type and size of sheaths and sheathless catheters				
Uhleman *et al*. (44)	5 *vs*. 6 Fr sheath	Discharge	13.7% *vs*. 30.5%	<0.001
Takeshita *et al*. (56)	4 *vs*. 6 Fr sheath	24 h	0% *vs*. 4%	0.08
Dahm *et al*. (55)	5 *vs*. 6 Fr sheath	1 month	1.1% *vs*. 5.9%	0.05
Kinoshita *et al*. (76)	6.5 Fr sheatless guides *vs*. 6 Fr guides	3 months for 6.5 Fr sheathless and 1 month for 6 Fr	0% *vs*. 5%	ND
Ang *et al*. (77)	6.5 Fr hydrophilic-coated sheathless guiding catheter *vs*. 5 Fr catheter	Discharge	0.1% *vs*. 0.7%	0.227
Wu *et al*. (78)	8 *vs*. 6 Fr sheath	1 year	11% *vs*. 19%	ND
Yoshimachi *et al*. (60)	Use of 5 Fr glidesheath slender	After removal of hemostasis device	0%	ND
Levin *et al*. (50)	7 Fr sheath	507±317 days	19%	ND
Mamas *et al*. (58)	6.5 Fr sheathless guide catheter	2 months	2%	ND
Nakamura *et al*. (79)	6.5 Fr sheathless guide catheter	6–9 months	0.67%	ND
Ruhnau *et al*. (47)	6 Fr sheath	4–68 weeks	3.6%	ND
Kwan *et al*. (80)	7 Fr sheathless guiding catheter	7 days and at 1 month	5% and 2.5%	ND
Tonomura *et al*. (81)	3 Fr sheathless guiding catheter	2–3 days	0%	ND
Trials evaluating different anticoagulation regiments on RAO				
Spaulding *et al*. (61)	0 *vs*. 2,000–3,000 IU *vs*. 5,000 IU heparin	Post-procedure	71% *vs*. 24% *vs*. 4.3%	<0.05
Bernat *et al*. (62)	2,000 *vs*. 5,000 IU heparin	3–4 h	5.9% *vs*. 2.9%	0.17
Plante *et al*. (49)	Heparin *vs*. bivalirudin	4–8 weeks	7.0% *vs*. 3.5%	0.18
Hahalis *et al*. (66)	2,500 *vs*. 5,000 IU heparin	1–3 days	15.9% *vs*. 14.0%	0.7
Pancholy *et al*. (67)	Warfarin *vs*. heparin	24 h and 1 month	18.6% *vs*. 9.6%; 13.9% *vs*. 5.2%	0.024; 0.01
Wong *et al*. (82)	Enoxaparin *vs*. heparin	6 weeks	3.8% *vs*. 3.7%	0.954
Aykan *et al*. (45)	2,500 *vs*. 5,000 IU heparin	1 month	5.5% *vs*. 1.2%	0.01
Pancholy *et al*. (83)	A priori *vs*. provisional heparin	24 hours and 1 month	7.5% *vs*. 7.0%; 4.5% *vs*. 5.0 %	0.84; 0.83
Schiano *et al*. (84)	5,000 IU *vs*. weigh-adjusted heparin (50 IU/kg)	Within 24 hours	0% *vs*. 0%	1.0
Pancholy *et al*. (63)	Intra-arterial *vs*. intravenous heparin	24 hours and 1 month	6% *vs*. 5.6%; 4% *vs*. 3.2%	>0.8; >0.6
Trials evaluating different sheath's insertion technique				
Pancholy *et al*. (85)	Seldinger *vs*. modified seldinger technique	1 month	4.3% *vs*. 3.9%	>0.05
Shantha *et al*. (86)	Introducer *vs*. without introducer sheath	Pre-discharge, 24 hours and 1 month	Propensity-matched OR: 0.20 (0.13–0.32); propensity-matched OR: 0.13 (0.07–0.25); propensity-matched OR: 0.18 (0.10–0.40)	<0.001; <0.001; <0.001
Trials evaluating different vasodilators regimens				
Dharma *et al*. (73)	500 µg nitroglycerin *vs*. placebo postprocedure	24 hours	8.3% *vs*. 11.7%	0.006
Ruiz-Salmerón *et al*. (70)	2.5 mg verapamil *vs*. 2.5 mg phentalamine after sheath insertion	20±18 days	3.0 % *vs*. 3.2%	ND
Beyer *et al*. (87)	30 mg nitroglycerin ointment and 40 mg lidocaine cream *vs*. placebo prior to TRA	24 hours	0/43 *vs*. 1/40	ND

ND, not definable; RAO, radial artery occlusion.

deflated until pulsatile bleeding occurred and 2 mL of air re-introduced in the bladder to achieve hemostasis) were compared with patients who received the rapid deflation technique. In this technique, exactly 15 minutes after TR Band application, radial artery patency was evaluated using the reverse Barbeau's test; the compression device was then deflated to the minimum volume of 7 mL while hemostasis was maintained. If bleeding occurred, 2 mL of air was re-introduced, radial artery patency was documented and the TR Band was removed after 2 hours. RAO was assessed 24 hours after the procedure, and was significantly lower in the rapid deflation technique group compared with the group receiving conventional hemostasis (2% *vs.* 14.9%, P=0.002).

Based on the above and other data, the Society for Cardiovascular Angiography and Intervention's (SCAI) Transradial Working Group has suggested that patent hemostasis should be used in all patients who undergo transradial procedures (41). The following process is proposed: withdrawal of the arterial sheath 2–3 cm, application of the hemostatic compression device 2–3 mm proximal to the skin entry site and removal of the sheath after tightening the device. Afterwards, the operator should decrease the pressure of the compression device to the point of mild pulsatile bleeding at the skin entry site and after 2–3 cycles of pulsatile bleeding retighten the device gradually to eliminate this pulsatile bleeding. Finally, radial artery patency is evaluated by using the reverse Barbeau's test.

Novel techniques that improve radial artery patency are under investigation. Simultaneous compression of the ipsilateral ulnar artery during radial artery patent hemostasis (the so called ULTRA technique), which increases blood flow velocity in the radial artery (89), while maintaining non-occlusive radial hemostasis showed promising results in a non-randomized study (90). Furthermore, in the recently published Prophylactic Hyperperfusion Evaluation Trial (PROPHET-II), ipsilateral ulnar artery compression, while applying patent hemostasis on the radial artery reduced the risk of RAO compared with the conventional patent hemostasis group at 24 hours (1.0% *vs.* 4.3%, P=0.0001) and at 30 days (0.9% *vs.* 3.0%, P=0.0001) (91).

Post-procedure compression duration

The duration of post-procedure compression has also been shown to be important: a study (92) has shown that only 2 hours of compression after the removal of the arterial sheath significantly reduced the risk of RAO 24 hours after the procedure as compared with the 6 hours of compression(5.5% *vs.* 12%, P=0.025). Another randomized study (73) demonstrated that >4 hours of compression increased the risk of RAO compared to <4 hours (OR 3.11, 95% CI: 1.66–5.82, P<0.001). Politi *et al.* (93) found that 15 minutes of post-procedure compression reduced the incidence of RAO compared with 2 hours (5% *vs.* 10%, P=0.05). Different hemostatic devices have been compared as well. Pancholy *et al.* (94) found that the use of the inflatable TR Band compression device reduced the risk of RAO at 24 hours (4.4% *vs.* 11.2%, P<0.005) and at 30 days (3.2% *vs.* 7.2%, P<0.05) after the procedure compared with the HemoBand device.

Treatment of RAO

While RAO is a usually subclinical condition and can be managed conservatively, in some cases active treatment may be needed. Zankl *et al.* (95) treated early symptomatic RAO with enoxaparin or fondaparinux for 4 weeks. After 1 month 87% of patients had a recanalized radial artery. Bernat *et al.* (62) compared RAO in patients undergoing TRA to receive 2,000 or 5000 IU of heparin. Occurrence of RAO was not statistically significant between the two groups (5.9% *vs.* 2.9%, P=0.17), but when treatment with 1-hour ipsilateral ulnar artery compression was applied, the risk of RAO was reduced in the 5,000 IU group (4.1% *vs.* 0.8%, P=0.03). Percutaneous techniques have also been used to treat RAO. Recanalization of the occluded radial artery with angioplasty has been described in a number of studies (28,29,32). The occluded part can be approached from the distal radial artery, the palmar arch or antegradely from the brachial artery.

Conclusions

TRA for coronary angiography and interventions has many benefits compared with the transfemoral approach. Its most important complication is RAO which could be a discouraging issue for many operators. Routine use of patent hemostasis, higher dose of anticoagulation and shorter post-procedure compression time have been shown to reduce the risk of RAO. All patients should be examined for radial artery patency before discharge. Novel studies and techniques are needed to improve strategies that minimize the incidence of this major complication of radial access.

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Footnote

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