Impact of Radial Compression Protocols on Radial Artery Occlusion and Hemostasis Time

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Abstract

Protocols for hemostasis after trans-radial approach (TRA) vary depending on the institute as there is no established evidence-based protocol. This study aimed to investigate the clinical implications of radial compression protocols. Consecutive patients who underwent outpatient invasive catheter angiography before and after April 2018 were treated with traditional and new protocols, respectively. Using the same hemostasis band, the amount and timing of deflation were fixed in the traditional protocol, whereas the air was removed as much as possible every 30 min in the new protocol. A total of 1,842 patients (71±10 years old, 77% male) were included. Compared with the traditional protocol group (n=1,001), the new protocol group (n=841) had a significantly lower rate of dual antiplatelet therapy (24% vs. 35%, p<0.001). The time required for complete hemostasis was approximately one-third with the new protocol (66±32 min vs. 190±16 min, p<0.001) with no clinically relevant bleeding. The incidence of radial artery occlusion (RAO) was 9.8% and 0.9% in the traditional and new protocol groups, respectively (p<0.001). After adjusting for covariates, the new protocol was associated with a shorter hemostasis time (odds ratio 0.01, p<0.001) and a reduced risk of RAO (odds ratio 0.09, p<0.001). Our new protocol for hemostasis after TRA was strongly associated with a shorter hemostasis time and a lower rate of RAO.

Introduction

The trans-radial approach (TRA) was established over the past three decades. It is now widely accepted in many situations as the standard access for invasive coronary catheter procedures [1, 2, 3, 4, 5, 6]. Since the radial arteries are located superficially in the forearm, access is easy and the method is safe. Unlike trans-femoral catheterization, TRA does not require long-term bed rest which could increase the risk of complications, such as venous thrombosis. Studies have demonstrated that TRA is generally safer than trans-femoral and trans-brachial approaches [7,8, 9, 10, 11].

Radial artery occlusion (RAO) is one of the most common and problematic complications and is reported to occur in 2%–11% of cases after TRA [12]. Since the radial artery is smaller in diameter than the femoral and brachial arteries, sheaths sometimes injure the radial artery walls during TRA, resulting in RAO after the procedure [13]. RAO is most often observed as a diminished or nonpalpable pulse and rarely causes numbness or coldness in the hands [14, 15]. Even when the patient is asymptomatic, RAO is a significant problem, as it may limit future access routes for coronary catheters [16]. Many clinical factors including the radial artery diameter, sheath size, and antiplatelet therapies, are thought to be risk factors for RAO [15, 17-20]. Of these, hemostasis time and the procedure itself are more easily modified. However, most hospitals use a commercially recommended protocol that focuses excessively on the risk of bleeding. This may be because an evidence-based optimal radial compression protocol is lacking. In this study, we sought to elucidate the impact of our new protocol on hemostasis time and the incidence of RAO after TRA.

Methods

The present study was a single-center retrospective observational study designed to evaluate the effectiveness of a new hemostasis protocol for trans-radial invasive cardiac catheterization. Consecutive patients who underwent invasive trans-radial coronary angiography at our outpatient clinic between April 2018 and July 2019 were treated with our new hemostasis protocol. The data was compared with that of the consecutive patients who were treated with the traditional hemostasis protocol between July 2016 and March 2018. The inclusion criteria were (1) outpatients who underwent trans-radial coronary angiography in the Department of Cardiology and (2) adult patients (³ 20 years old). In addition, (1) patients who underwent catheter intervention, (2) patients with acute coronary syndrome, and (3) patients with hemodialysis or cirrhosis, were excluded. Coronary angiography was performed by an experienced cardiologist using a TRA. After inserting a 4- or 5-Fr sheath (Radifocus® Introducer IIH, Terumo Corporation, Tokyo, Japan), 50 U/kg of heparin was injected intravenously. Immediately after the procedure, the sheath was removed. Subsequently, hemostasis was achieved using the traditional commercially recommended protocol before April 2018, after which the new protocol was used. We used a commercially available hemostasis band (TR band ™; Terumo Corporation, Tokyo, Japan) in both protocols. In the traditional protocol, after initially injecting 16 mL of air into the band, patients were transferred to a postoperative monitoring room, where 2 mL of air was immediately removed. Then, 4 and 10 mL of air was removed 2 and 1 h later, respectively (Figure 1, upper panel). If the puncture site bled, 2 mL of air was added. Once the air has been completely removed, the band was detached and hemostasis was completed. In the new protocol, after initially injecting 16 mL of air, as much of the air was removed as possible without bleeding, immediately after the patient was transferred to the recovery room. The same removal procedure was repeated every 30 min until the air was completely removed (Figure 1, bottom panel). Written informed consent was waivered given the retrospective non-invasive observational nature of the study under the Ethical Guidelines for Medical and Health Research Involving Human Subjects issued by the Japanese Ministry of Health, Labor and Welfare. The study protocols complied with the guidelines of the Declaration of Helsinki and were approved by the of the Ethics Committee of The Sakakibara Heart Institute of Okayama.

Outcome measures

The incidence of RAO was tracked as the primary efficacy endpoints, and the time to achieve hemostasis was the co-primary endpoint. The rate of clinically relevant bleeding defined as bleeding requiring surgical treatment, blood transfusion, or unexpected hospital stay was counted as the safety endpoint. The time required to achieve hemostasis was measured from the time when the sheath was removed to the time when the band was detached. Hemostasis time was considered to be prolonged if it exceeds 180 min. RAO was assessed 6 months after the procedure by physical examination and/or ultrasound examination by an experienced cardiologist. Ultrasound was optional and not routinely performed. Clinically relevant bleeding was defined as a bleeding event that required surgical treatment, blood transfusion, or hospital admission.

Statistical analysis

The data are presented as the mean ± standard deviation for continuous variables and as frequency (%) for categorical variables. Group differences were evaluated using the Student's t-test for continuous variables and the Fisher's exact tests for categorical variables. Logistic regression models were applied to assess the effectiveness of the new protocol after adjusting for confounders. All statistical analyses were performed using R (version 4.0.3, Vienna, Austria). Two-sided p value <0.05 was considered significant in all analyses.

Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request

Results

Population

A total of 1,846 patients underwent trans-radial coronary angiography. After excluding three patients who required hemodialysis and one patient with cirrhosis, 1,842 patients (1,001 and 841 in the traditional and new protocol groups, respectively) were finally included in the analysis (Figure 2). Patient characteristics are summarized in Table 1. Age, sex, systolic blood pressure, body surface area, body mass index, creatinine level, and platelet count were not significantly different between the two groups. The diastolic blood pressure was slightly lower in the new protocol group. A larger sheath was used more frequently in the new group. The prevalence of hypertension and dual antiplatelet therapy was also higher in the new group.

Primary endpoint: radial artery occlusion

A 6-month follow-up was available for 1315 patients (71.4%). The incidence of RAO was less than one-tenth. RAO was detected in 64 (9.9%) with the traditional protocol and 6 (0.9%) with the new protocol (Figure 3, upper panel). We also constructed multivariate logistic regression models to assess the association between RAO and its risk factors. Since the protocol and hemostasis were very closely correlated as stated below, we created two models: one with the new protocol and the other with time to hemostasis. The model showed that both the new protocol (OR 0.09, $p<0.0001$) and time of hemostasis (OR 1.18 /10 min, $p<0.0001$) were significantly associated with RAO (Table 2). The number of previous trans-radial catheterization and body surface area were also significantly associated with RAO in both models.

Time to complete hemostasis

The time to achieve hemostasis was significantly shorter in the new protocol. It was approximately one-third of that in the traditional protocol (190 ± 16 min in the traditional protocol vs. 66 ± 32 min in the new protocol, $p < 0.001$; Figure 3, lower panel). Prolonged hemostasis time (>180 min) was required for 294 (29%) and 4 (0.5%) patients in the traditional and new protocols, respectively. None of the patients in either group experienced clinically relevant bleeding that required surgical treatment, blood transfusion, or hospital admission.

To investigate the factors associated with prolonged hemostasis time, a multivariable logistic regression model was constructed (Table 3). The model demonstrated a strong association between the new protocol and shorter hemostasis time (odds ratio [OR] 0.01; $p < 0.0001$) after adjusting for several covariates. The use of antiplatelet therapies was also significantly associated with prolonged hemostasis (OR 1.65 and 2.55, $p = 0.01$ and $p < 0.001$, for single and dual antiplatelet therapy, respectively).

Discussion

TRA is the standard and most common approach for coronary angiography today. However, an evidence-based radial compression protocol is still lacking. In this relatively large cohort study, we demonstrated that our new protocol was significantly and strongly associated with (1) a lower incidence of RAO (the primary endpoint) and (2) a shorter hemostasis time (the co-primary endpoint) compared with the traditional commercially recommended radial compression protocol. The effect size of this new protocol was large, suggesting a potentially large clinical benefit for patients.

In the past three decades, studies have shown the advantage of TRA over the traditional trans-femoral approach, mainly in terms of the incidence of complications [11]. TRA causes fewer puncture site complications and requires less restriction of body movement after the procedure [21]. However, the traditional radial compression protocol still takes 2 – 3 hours and sometimes causes RAO, which remains the most frequent complication of TRA [12]. Since it restricts the use of the artery for future procedures, not only catheter angiography but also as a conduit for coronary artery bypass grafting or arteriovenous fistula for hemodialysis, it is important to prevent RAO regardless of whether it is symptomatic or asymptomatic.

One reported mechanism of RAO is acute arterial thrombosis caused by arterial wall injury, some of which resolves later, while others remain occluded [22]. Another mechanism is intimal-medial thickening resulting from vascular injury [23, 24]. Since excessive pressure during hemostasis can damage the arterial wall, compression for hemostasis should be performed with appropriate pressure for as short a time as possible. The RAO International Group published a consensus paper in 2019, focusing on the incidence, risk factors, and prevention of RAO [12]. In the paper, the group recommends ‘non-occlusive’ or ‘patent’ hemostasis, as well as short compression, since complete occlusion of the artery is a risk for RAO [25]. As stated in the paper, the suggested method using an oximetry-plethysmography device requires a significant work burden. In contrast, our new protocol does not require a special device, although the amount of air is always just before bleeding occurs, and thus the artery is likely to be kept patent. As a result, the incidence of RAO in the new protocol was low (0.9%).

Another important clinical implication of our new protocol is a significant reduction in hemostasis time. Invasive catheter angiography is the gold standard for evaluating anatomical stenosis of the coronary artery and is often performed in an outpatient setting. However, the long resting time after the procedure sometimes prevents patients from returning home on the same day. Outpatient invasive catheter procedures are easier and more accessible if the resting time after the procedure can be shortened. Since the new protocol requires air removal every 30 min, the number of visits to patients may increase in the new protocol. However, a nurse generally has to stay in the patient recovery room until the hemostasis is completed to watch them. Therefore, a short resting time will reduce nurses' workload and lead to more cost-effective hospital management.

Recently, the distal radial artery approach has been reported as a new puncture method for coronary angiography (26,27,28). This technique may also enable a short-time hemostasis and lower rates of RAO (27). However, this technique is relatively difficult and cannot be applied to all patients. Besides, a couple of unique complications, such as scaphoid fracture due to injury of the feeding arteries, have been reported (28). Thus, further evaluation is necessary before the distal radial artery becomes the standard method.

Limitations

Our study results are best understood in the context of several limitations. First, this is an observational study in which we evaluated the clinical work performed in our hospital. Although we employed statistical analysis to mitigate the risk of confounding and the observed effect size was large, our findings need to be validated in randomized control studies. Second, there were a significant number of patients for whom the 6-month radial artery patency data were unavailable, even though over 1,300 patients were finally evaluated. Third, we did not routinely perform ultrasound examinations to check for RAO. There may have been some patients whose radial arteries were actually patent. However, even with ultrasound-visible blood flow, an artery without detectable palpitation may still not be feasible for TRA. Fourth, we did not routinely assess the radial artery diameter using ultrasound. Next, the incidence of minor hematoma that does not require surgical treatment, blood transfusion, or hospital stay was not recorded. Finally, the entire study population were Asian adults, whose body size and body mass index are substantially smaller than those in North America and Europe. Hence, the results may need to be validated in non-Asian countries.

Conclusions

Our new radial compression protocol for hemostasis after TRA was strongly associated with a shorter hemostasis time and a lower rate of radial artery occlusion. This approach decreases the post-procedural bed rest time, resulting in even fewer complication rates.

Abbreviations

OR; odds ratio

RAO; radial artery occlusion

TRA; trans-radial approach

Declarations

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Tables

Table 1. Patient Characteristics

	Traditional Protocol N = 1,001	New Protocol N = 841	p-value
Age, years	71 ± 10	71 ± 10	0.20
Male	756 (76%)	660 (78%)	0.15
Systolic BP, mmHg	131 ± 20	130 ± 18	0.30
Diastolic BP, mmHg	74 ± 12	72 ± 12	0.021
BMI, kg/m^2	24.6 ± 5.4	24.6 ± 3.5	0.80
BSA, m^2	1.67 ± 0.20	1.69 ± 0.18	0.059
Creatinine, mg/dL	0.90 ± 0.36	0.92 ± 0.19	0.30
Platelet, $/mm^3$	19.7 ± 7.7	20.2 ± 5.8	0.12
Sheath size, Fr			<0.001
4	966 (97%)	767 (91%)	
≥ 5	35 (3.5%)	74 (8.8%)	
Previous cath, times	3.78 ± 2.99	3.33 ± 2.99	0.001
Hypertension	721 (72%)	513 (61%)	<0.001
Diabetes	388 (39%)	294 (35%)	0.10
SAPT	378 (38%)	330 (39%)	0.50
DAPT	347 (35%)	206 (24%)	<0.001
DOAC	56 (5.6%)	34 (4.0%)	0.13
Warfarin	43 (4.3%)	23 (2.7%)	0.079

Table 2. Risk for Radial Artery Occlusion

	Odds ratio	95% CI	p-value
New protocol	0.09	0.04 - 0.22	<0.001
Previous cath times	1.17	1.10 - 1.25	<0.001
SAPT	1.43	0.66 - 3.10	0.37
DAPT	1.52	0.68 - 3.39	0.31
Body surface area	0.09	0.02 - 0.37	<0.001

	Odds ratio	95% CI	p value
Time of hemostasis / 10 min	1.18	1.11 - 1.26	<0.001
Previous cath times	1.16	1.09 - 1.24	<0.001
SAPT	1.34	0.62 - 2.92	0.46
DAPT	1.42	0.64 - 3.17	0.39
Body surface area	0.09	0.02 - 0.37	<0.001

Table 3. Odds for Prolonged Hemostasis Time (>180 min)

	Odds ratio	95% CI	p-value
New protocol	0.01	0.00 - 0.03	<0.001
Male	0.83	0.53 - 1.29	0.41
Age / year	1.01	0.99 - 1.02	0.56
Sheath size ≥ 5Fr	0.48	0.20 - 1.15	0.10
Platelet / /mm^3	0.99	0.96 - 1.01	0.39
Creatinine / mg/dL	1.31	0.82 - 2.09	0.26
Hypertension	0.87	0.64 - 1.19	0.38
Diabetes	0.94	0.71 - 1.26	0.69
Previous cath / times	1.00	0.95 - 1.05	>0.99
SAPT	1.65	1.12 - 2.42	0.01
DAPT	2.55	1.70 - 3.80	<0.001
DOAC	1.78	0.99 - 3.18	0.05
Warfarin	1.14	0.57 - 2.28	0.71
Systolic BP / mmHg	1.00	0.99 - 1.01	0.87
BSA / m^2	2.08	0.52 - 8.35	0.30
BMI / kg/m^2	0.96	0.91 - 1.02	0.18

Figures

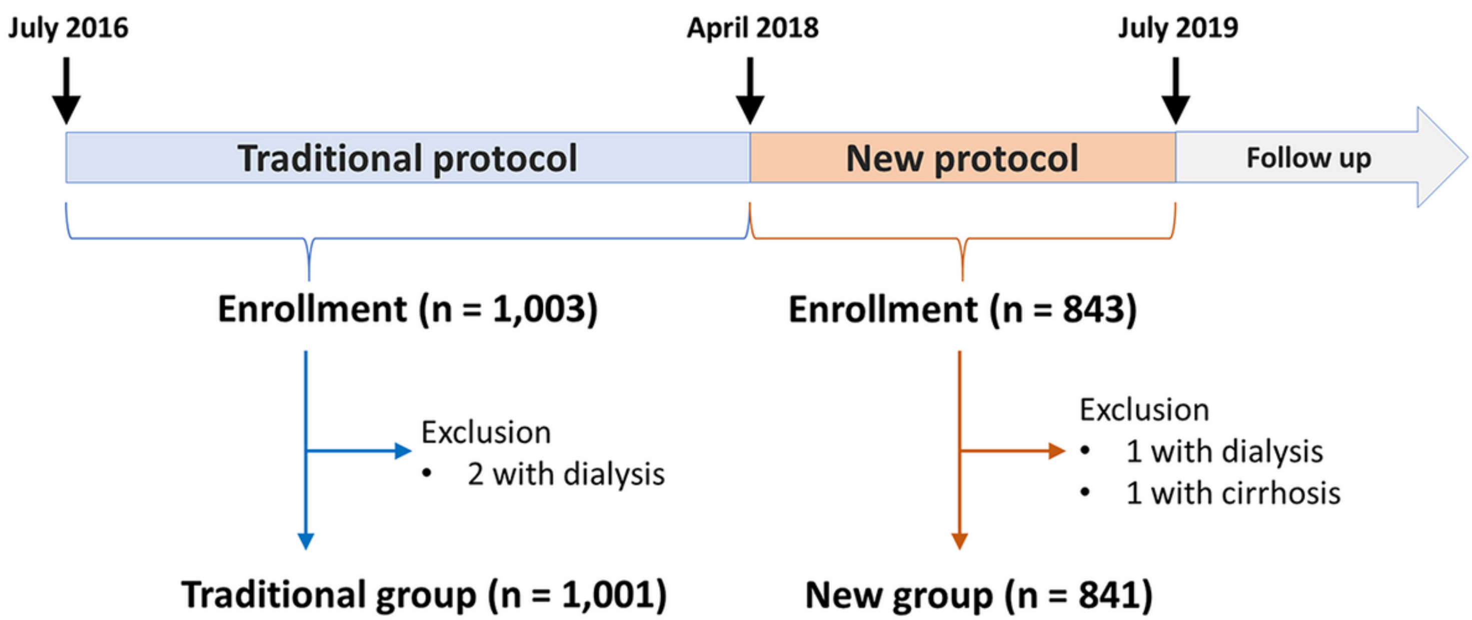

Figure 1

Radial compression protocols In both protocols, 16 ml of the air is injected and then gradually removed. In the traditional protocol, the amount of the timing of air removal is fixed, whereas the air is removed as possible without bleeding in thein the new protocol.

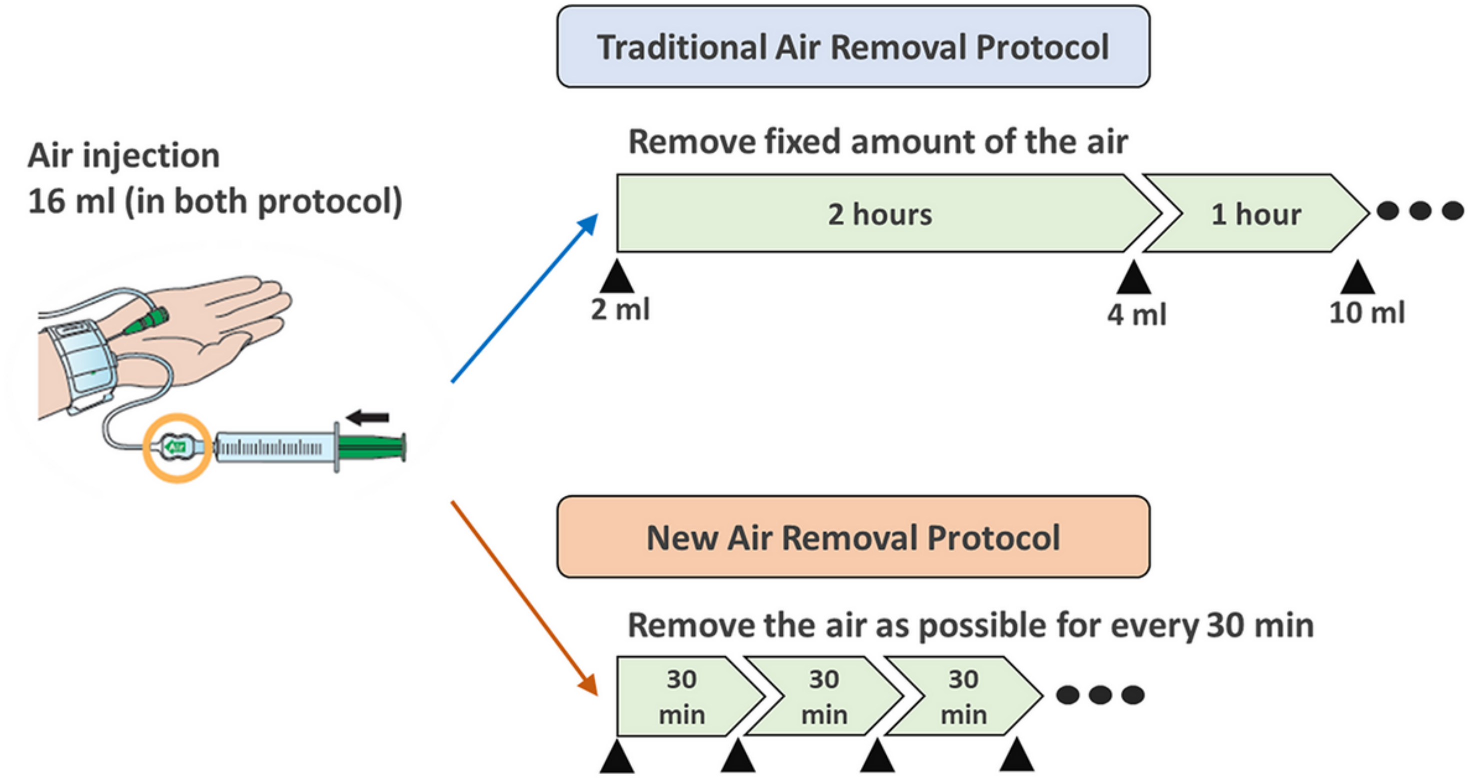

Figure 2

Patient enrollment chart In total, 1,001 and 841 patients were enrolled in the analysis.

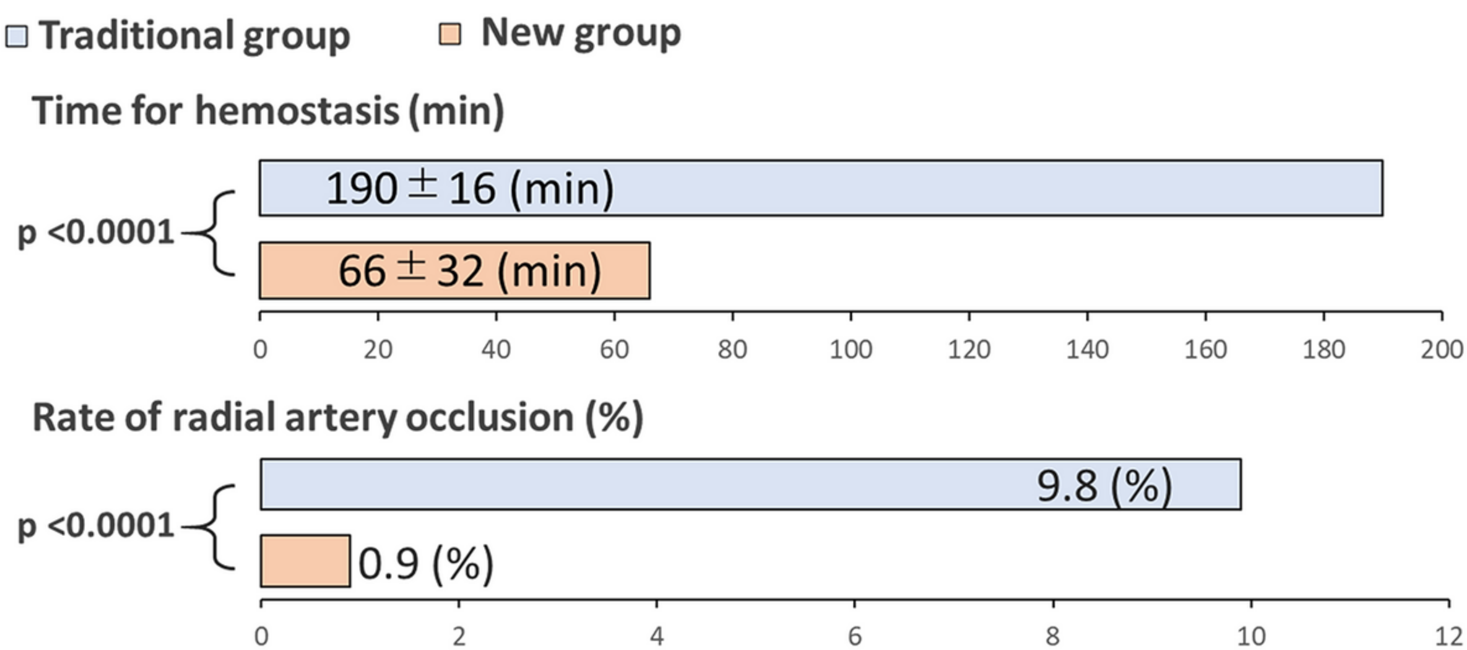

Figure 3

Radial compression time and the rate of radial artery occlusion The new protocol group had dramatically shorter time for complete hemostasis and a lower rate of radial artery occlusion.