Clinical accuracy of reverse Barbeau test in the diagnosis of radial artery occlusion after transradial catheterization

Precisão clínica do teste de Barbeau reverso no diagnóstico de oclusão da artéria radial após cateterização transradial

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ABSTRACT – Background: Radial artery occlusion is an infrequent complication of transradial catheterization. Assessment of radial artery occlusion is a critical aspect of clinical care, and it should be done with an additional test, commonly by a plethysmographic test (reverse Barbeau test) or ultrasound (Doppler), the last is the gold standard. The objective of this study was to evaluate the accuracy of the reverse Barbeau test in detecting radial artery occlusion after transradial catheterization. Methods: A study carried out in two centers encompassing patients submitted to procedures by radial access. All patients received at least 5,000IU of heparin. Sheaths were immediately removed after the procedure, using a patent hemostasis protocol. Patency of the radial artery was verified by reverse Barbeau test and duplex Doppler evaluation within the first 24 hours. Results: A total of 350 patients were enrolled, with a mean age of 61.7 (±9.7) years. Radial artery occlusion was verified after the procedure in 19 (5.4%) patients, using duplex Doppler scan. Application of reverse Barbeau test had the following results: 64.0% type A curve, 15.7% type B, 8.3% type C, and 12.0% type D (the last suggesting occlusion). With reverse Barbeau test, patients with confirmed occlusion by ultrasound evaluation, 21.1% would be missed by a false-negative test, and in the ones, without radial artery occlusion, 8.2% would be misdiagnosed as having it (sensibility 78.9%; specificity 91.8%). Conclusion: Reverse Barbeau test has good accuracy to detect radial artery occlusion, and it is a good option for clinical day use, although using reverse Barbeau test results in the overestimation of radial artery occlusion.

Keywords: Transradial catheterization; Radial artery occlusion; Ultrasonography, doppler

RESUMO – Introdução: A oclusão da artéria radial é uma complicação infrequente do cateterismo transradial. Sua avaliação é um aspecto crítico da assistência clínica, devendo ser feita com exame complementar, em geral um teste pletismográfico (teste de Barbeau reverso) ou ultrassonografia (Doppler) – sendo o último o padrão-ouro. O objetivo deste estudo foi avaliar a precisão do teste de Barbeau reverso na detecção de oclusão da artéria radial após cateterismo transradial. Métodos: Estudo de dois centros com pacientes submetidos a procedimentos por via radial. Todos receberam pelo menos 5.000UI de heparina. As bainhas foram retiradas imediatamente após o exame, utilizando um protocolo de hemostasia patent. A perviedade da artéria radial foi verificada pelo teste de Barbeau reverso e por avaliação Doppler nas primeiras 24 horas. Resultados: Foram incluídos 350 pacientes, com média de idade de 61,7 (±9,7) anos. A oclusão da artéria radial foi verificada após o procedimento em 19 (5,4%) pacientes, por meio de Doppler. A aplicação do teste de Barbeau reverso teve os seguintes resultados: 64,0% curva tipo A, 15,7% tipo B, 8,3% tipo C e 12,0% tipo D (a última sugere oclusão). Com o teste de Barbeau reverso, entre os pacientes com oclusão confirmada pela avaliação ultrassonográfica, 21,1% deixariam de ser diagnosticados devido a um exame falso-negativo, e, entre aqueles sem oclusão da artéria radial, 8,2% seriam diagnosticados erroneamente como a tendo (sensibilidade de 78,9% e especificidade de 91,8%). Conclusão: O uso do teste de Barbeau reverso tem boa precisão na detecção de oclusão da artéria radial, sendo uma opção para uso clínico diário, embora sua utilização resulte na superestimação de oclusão da artéria radial.
INTRODUCTION

The use of transradial access (TRA) for diagnostic and interventional procedures has increased over the years, becoming the preferred vascular access route in most countries.\(^1\) Many pieces of evidence confirm that TRA not only reduces the risk of access-site bleeding and vascular complications, but it also decreases mortality rates in high-risk patients, like those presenting with acute coronary syndromes (ACS). Transradial access also improves patient comfort, saves costs, and has easier post-procedural management.\(^2,3\)

Notwithstanding its widespread application, some problems still exist. One limitation is the development of post-procedural radial artery occlusion (RAO), which is the most frequent complication of TRA. The reported incidence of RAO ranges from 1% to 12%, and the mean incidence of early (within 24 hours) RAO is 7.7%\(^4\). The dual blood hand supply from the palmar arch usually leads to a benign nature of such event. The occurrence of radial occlusion is asymptomatic in most cases, but, more important, once the occlusion happens, it potentially avoids ipsilateral TRA for future procedures, and further use as a conduit for bypass surgery or fistula creation in hemodialysis patients.\(^5\)

Using smaller caliber catheters, an adequate dose of heparin administration, immediate sheath removal after the procedure, patent hemostasis technique, and a brief time of compressive bandage are the key elements to reduce the risk of artery occlusion.\(^6,7\) Evaluation of RAO before discharge remains suboptimal, and simple palpation-based assessment of artery pulsation is the standard method of evaluation.\(^8\) Of note, the radial pulse does not exclude radial occlusion because of the possibility of collateral circulation and can lead to significant underestimation of RAO. Vascular Doppler ultrasound can assess more accurately the arterial flow, allowing important additional information, such as thrombus or dissections.\(^9\) The reverse Barbeau test (RBT) provides a simple and inexpensive method of evaluation of radial artery patency.\(^10\)

There is no conclusive evidence for the superiority of Doppler ultrasound evaluation over the RBT; therefore, our objective was to investigate whether RBT has the same efficacy in detecting RAO compared to duplex Doppler scans.

METHODS

This is a prospective, non-randomized, observational study carried out in two centers, investigating the diagnostic value of RBT on detection of RAO in patients submitted to diagnostic and/or therapeutic percutaneous coronary procedure by radial access. We considered all adult patients undergoing transradial catheterization at two centers, between January 2019 and December 2019 for inclusion. With an all-comers design, eligible patients were aged ≥18 years, with a clinical indication for coronary angiography (ad hoc angioplasty allowed) or percutaneous coronary intervention (PCI) if they met the following prerequisites: choice of the operator to use the TRA route and use of 5-F or 6-F sheath size. Baseline patency of the palmar arch, by Allen test or Barbeau test, was not obligatory. Exclusion criteria were primary angioplasty due to acute myocardial infarction, intubation and complications during the procedure (cardiac arrest, pulmonary edema, cardiogenic shock, and stroke). We presented the study protocol to the institutional medical ethics committees of all participating hospitals to comply with local standards (Research Ethics Committees protocol 4785/2017, CAAE 68678317.0.3001.5462). All patients provided written informed consent.

Transradial procedure

Local anesthesia was administered with a subcutaneous injection of 1% lidocaine after skin preparation. Radial artery access was obtained using either anterior or counterpuncture technique, based on the operator’s preference, using a 21-gauge bare needle or 20/22 gauge sheath-covered needle, after which a 5F or 6F hydrophilic sheath was inserted over a guidewire. Then, the patient received heparin (5,000IU) through the radial sheath as an intra-arterial bolus. Additional heparin was given in cases of PCI, for a total of 100IU/kg. No routine intravenous sedation was given. The use of additional medication, either vasodilators or analgesics, was left to the operator’s discretion. Transradial coronary angiography and/or PCI were performed, according to standard techniques, at the operator’s discretion.

Arterial hemostasis

After the procedure, a pneumatic compression device designed to assist hemostasis of the radial artery was applied according to the institutional protocol. Shortly, the sheath was initially pulled by approximately 2cm to 4cm. To remove any residual thrombus, 3mL to 5mL of blood were aspirated through the sheath. The device was applied to the patient, positioning the green marker (in the center of the larger balloon) exactly at the puncture site to allow visualization and control of bleeding. The balloon was inflated, injecting 15mL of air, and then the sheath was removed, observing the absence of active bleeding. In the presence of bleeding, up to 3mL of additional air was injected to achieve complete hemostasis. Next, the device was deflated to the bleeding point. At that moment, enough air amounts were reintroduced from the bleeding point (up to 1mL in most cases) to achieve hemostasis. No fixed amount of air was used, but just the minimum necessary to obtain hemostasis. Radial artery patency was subsequently evaluated. Some patients received heparin (5,000IU) through the radial sheath as an intra-arterial bolus. Additional heparin was given in cases of PCI, for a total of 100IU/kg. No routine intravenous sedation was given. The use of additional medication, either vasodilators or analgesics, was left to the operator’s discretion. Transradial coronary angiography and/or PCI were performed, according to standard techniques, at the operator’s discretion.
assessed by plethysmography and pulse oximetry evaluation, with the sensor placed over the thumb or index finger, and transient occlusion (manual pressure) of the ulnar artery. One-hour after diagnostic procedure or 2 hours after intervention, 3mL of air was removed every 15 minutes until complete deflation. When all air was removed, the device was removed and the access site was covered with a simple bandage, with caution to not encircle the entire wrist.

Assessment of radial patency

**Duplex ultrasonography**

Radial artery patency was evaluated by vascular duplex Doppler ultrasound, using a 6MHz to 13MHz vascular transducer with M-Turbo® ultrasound scanner (Fujifilm SonoSite), or a 7.5MHz vascular transducer with PowerVision 6000 ultrasound scanner (Toshiba), performed in all patients within 24 hours of the removal of the compression band. Radial artery occlusion was defined by the absence of anterograde flow. Pulse-Doppler interrogation of the waveform was done to rule out collateral flow suggesting upstream occlusion. This method is considered the gold standard for arterial flow assessment.11

**Oximetry-plethysmography test**

Reverse Barbeau test was conducted by the following protocol: with the patient in a sitting position, the upper extremity was placed in its anatomically relaxed position with flexed elbow. A plethysmographic sensor (PM-60, Shenzhen Mindray Bio-Medical Electronics Co.) was applied to the index finger or the thumb, and the presence of the oximetry-plethysmographic signal was verified. The ulnar artery was compressed, and the shape of the plethysmographic wave was observed. The waveforms were classified based on previously published classification, as pattern A, B, C, or D:12 pattern A if no damping of the tracings immediately after ulnar artery compression; pattern B if slight damping of the tracings; pattern C if loss of the tracings followed by recovery within 2 minutes and pattern D if loss of the tracings without a recovery in 2 minutes. This last pattern demonstrates occlusion.

Both tests have clearly defined criteria for diagnosis, with no indeterminate results. To avoid biases caused by changes in the actual patency status, which can affect the diagnostic accuracy of RBT, both tests were done sequentially.13

**Statistical analysis**

The primary analysis of the study was a comparison between RBT results with the results of the best available test for diagnosing RAO (vascular duplex Doppler ultrasound) in the same participants, for the detection of early RAO. To evaluate the performance of RBT, we conducted studies of agreement or concordance between them. Since both tests were realized sequentially, there was no missing data to handle. Standard estimations of sensibility, specificity, and positive and negative predictive values were obtained by using a 2x2 contingency table. Confidence intervals for sensitivity, specificity, and accuracy are Clopper-Pearson confidence intervals. To investigate the accuracy of RBT, with an expected sensitivity of 0.95, in a population where the disease prevalence was 0.05, and we required the lower 95% confidence limit to be >0.65 with 0.95 probability, our calculated sample size was 16 patients with RAO and 304 controls.14

Continuous variables were described as mean±standard deviation and categorical variables were expressed as frequency (percentage of the group). A p-value of <0.05 was considered statistically significant. All analyses were performed using Statistical Package for Social Science (SPSS), version 22 and MedCalc, version 19.4.1 (MedCalc Software Ltd).

**RESULTS**

A total of 350 patients underwent transradial catheterization and were enrolled between January 2019 and December 2019, with a mean age of 61.7 (±9.7) years. The majority was male (58.3%), 38.0% had diabetes, and 79.4% had hypertension. Diagnostic coronary angiography was the predominant procedure with 95.1% of cases (Table 1).

**Table 1. Baseline clinical and procedure characteristics**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, years</td>
<td>61.7±9.7</td>
</tr>
<tr>
<td>Sex, male</td>
<td>204 (58.3)</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>77.7±15.2</td>
</tr>
<tr>
<td>Height, cm</td>
<td>165.5±15.2</td>
</tr>
<tr>
<td>BMI</td>
<td>28.3±4.9</td>
</tr>
<tr>
<td>Right-handed</td>
<td>339 (96.9)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>278 (79.4)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>133 (38.0)</td>
</tr>
<tr>
<td>Smoker</td>
<td>59 (16.9)</td>
</tr>
<tr>
<td>Dyslipidemia</td>
<td>236 (67.4)</td>
</tr>
<tr>
<td>Prior ipsilateral transradial catheterization</td>
<td>70 (20.0)</td>
</tr>
<tr>
<td><strong>Clinical</strong></td>
<td></td>
</tr>
<tr>
<td>Stable</td>
<td>316 (90.3)</td>
</tr>
<tr>
<td>ACS</td>
<td>34 (9.7)</td>
</tr>
<tr>
<td><strong>Procedure</strong></td>
<td></td>
</tr>
<tr>
<td>Diagnostic</td>
<td>333 (95.1)</td>
</tr>
<tr>
<td>ad hoc PCI</td>
<td>11 (3.1)</td>
</tr>
<tr>
<td>PCI</td>
<td>6 (1.7)</td>
</tr>
<tr>
<td>Anterior puncture</td>
<td>175 (50.0)</td>
</tr>
<tr>
<td>Sheath size (SF)</td>
<td>315 (90.0)</td>
</tr>
<tr>
<td>Puncture attempt (n)</td>
<td>1.3±0.7</td>
</tr>
</tbody>
</table>

Parameters are described as median ± standard deviation or n (%). BMI: body mass index; ACS: acute coronary syndrome; PCI: percutaneous coronary intervention.
Radial artery occlusion was verified after the procedure in 19 (5.4%) patients, using duplex Doppler scan. None of the patients with RAO experienced any sign or symptom of hand ischemia requiring specific treatment. Application of RBT had the following results: 64.0% type A curve (224 patients), 15.7% type B (55 patients), 8.3% type C (29 patients), and 12.0% type D (42 patients); the last suggesting occlusion. With RBT, patients with confirmed occlusion by ultrasound evaluation, 21.1% would be missed by a false-negative test, and in the ones, without RAO, 8.2% would be misdiagnosed as having RAO. Remarkably pulse was absent in only 2.5% of patients.

Reverse Barbeau test sensitivity and specificity were 78.9% (95%CI 54.4%-93.9%) and 91.8% (95%CI 88.3%-94.6%), respectively (Table 2). With the incidence of RAO in our sample, accuracy was 91.1% (95%CI 87.6%-93.9%). Negative predictive value was 98.7% (95%CI 97.01%-99.45%) and positive predictive value was 35.7% (CI 95% 26.5%-46.0%) (Figure 1).

**DISCUSSION**

We compared two methods that evaluate RAO after a transradial approach. Our results show that the use of the oximetry-plethysmography test is less sensitive, but still have high specificity, and could facilitate the workflow in cath labs. It is acceptable to use RBT as the first method to detect RAO in routine clinical practice, due to its broad availability and limited cost, followed by ultrasound with Doppler to confirm RAO in patients with an abnormal initial test.

According to an international survey, routine assessment of radial artery patency before discharge remains suboptimal, and only 60% of operators performed it regularly, many of whom use simple palpation-based methods. It is not recommended clinical estimation by radial pulse palpation, because it can lead to significant underestimation of RAO. Also, palpation of the radial pulsation does not imply radial artery patency. Macro-collateral circulation from the palmar arch can contribute to pulse. The distal stump of an occluded radial artery may have up to 70% of mean arterial pressure because of the palmar arch circulation or other collateral arterial connections.

Barbeau test was proposed for the detection of insufficient collaterals to the hand or incomplete palmar arch before cannulation of the radial artery. It is more accurate and objective than the previous modified Allen test and has become the preferred method for evaluation of the hand arterial vascular supply. RBT is a slightly modified test, used to evaluate radial patency, and many centers have adopted it for the diagnostic of RAO as the main method of evaluation after catheterization, given its simplicity.

Ultrasound with Doppler assessment is the most valuable method for RAO detection, since it can provide not only an accurate estimation of radial flow but also important anatomical information, such as arterial thrombus or dissections, being the current gold standard for it. Clinical assessment with mere palpation underestimates, and RBT alone overestimates occlusion rates. Thus, Doppler examination is essential in diagnosing the RAO.

Few studies compared both methods. Bajaj et al. described three cases in which ultrasound analysis did not confirm an initial positive RBT. Venkatesan et al. compared both examinations in a series of 105 patients, and reported specificity of RBT of 86.1%, within our confidence interval. As they tested with Doppler ultrasound only the patients with RBT indicating occlusion, it is impossible to calculate sensibility. Recently, Jirous et al. described a large series of 500 patients, in which they carried out both tests, RBT and Doppler, with a perfect match between both methods. But they had only two RAO (0.4%), and with that minimal number, any comparison of the two tests is not reasonable.

Importantly, reported rates of RAO depend on the timing of evaluation, with early RAO frequencies being sig-

<table>
<thead>
<tr>
<th>Table 2. Contingency table: diagnosis of radial artery occlusion, by Barbeau test and Doppler</th>
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<tbody>
<tr>
<td>Doppler USG</td>
</tr>
<tr>
<td>RAO present</td>
</tr>
<tr>
<td>RBT +</td>
</tr>
<tr>
<td>-</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

USG: ultrasound; RAO: radial artery occlusion; RBT: reverse Barbeau test.

**Figure 1.** Positive and negative predictive values of reverse Barbeau test on radial artery occlusion diagnosis.
Clinical accuracy of reverse Barbeau test in the diagnosis of radial artery occlusion after transradial catheterization

CONCLUSION

In the present study, the use of reverse Barbeau test resulted in a good accuracy in detecting radial artery occlusion, as compared to the duplex Doppler scan. Although this test is still a suitable option for clinical day use as a triage method, giving its widespread availability and low costs, its use results in overestimation of occlusion cases. Therefore, we should use an ultrasound Doppler examination to confirm radial artery occlusion in patients with an abnormal initial test.

SOURCE OF FINANCING

None.

CONFLICTS OF INTEREST

The authors declare there are no conflicts of interest.

CONTRIBUTION OF AUTHORS

Conception and design of the study: RLS, PBA and JRCJ; data collection: RLS, PFRB, RMJ, FBF and RGV; data interpretation: RLS, PFRB, RMJ, FBF and RGV; text writing: RLS, PFRB and RMJ; approval of the final version to be published: RLS, PFRB, RMJ, PBA, AAC, FBF, RGV, RMMV, AGMS, FF and JRCJ.

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