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Original Article

# Risk Factors for Radial-to-Femoral Artery Pressure Gradient in Patients Undergoing Cardiac Surgery With Cardiopulmonary Bypass

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*Objective:* To identify risk factors associated with radial-to-femoral pressure gradient during cardiac surgery with cardiopulmonary bypass (CPB).

*Design:* This is a retrospective, observational study.

*Setting:* Single specialized cardiothoracic hospital in Montreal, Canada.

*Participants:* Consecutive patients that underwent heart surgery with CPB between 2005 and 2015 (n = 435).

*Interventions:* None.

*Measurements and Main Results:* A radial-to-femoral pressure gradient occurred in 146 patients of the 435 patients (34%). Based on the 10,000 bootstrap samples, simple logistic regression models identified the 17 most commonly significant variables across the bootstrap runs. Using these variables, a backward multiple logistic model was performed on the original sample and identified the following independent variables: body surface area ($m^2$) (odds ratio [OR] 0.08, 95% confidence interval [CI] 0.030-0.232), clamping time (minutes) (OR 1.01, 95% CI 1.007-1.018), fluid balance (for 1 liter) (OR 0.81, 95% CI 0.669-0.976), and preoperative hypertension (OR 1.801, 95% CI 1.131-2.868).

*Conclusion:* A radial-to-femoral pressure gradient occurs in 34% of patients during cardiac surgery. Patients at risk seem to be of smaller stature, hypertensive, and undergo longer and more complex surgeries.



*Key Words:* blood pressure; cardiopulmonary bypass; pressure gradient; radial artery; femoral artery

UNDER MOST CIRCUMSTANCES, radial blood pressures accurately reflect the central pressures. However, during cardiac surgery involving cardiopulmonary bypass (CPB), a significant difference appears in some patients causing the radial pressure to significantly underestimate the central pressure.[1–16] Since it was first described by Stern et al[1] in 1985, the central-to-peripheral arterial pressure gradient has

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been frequently reported in patients undergoing cardiac surgery. In the literature, its incidence ranges widely from 10% to 87%, depending on the length of procedure, the type of surgery performed and the value of gradient considered significant.[1,2,9,11,15–17] This wide range of values illustrates the need for further studies. If arterial pressure measurements in the radial line lead to underestimation of the central pressure, then excess fluid, vasoactive, and inotropic medications may be used erroneously.

The pathophysiology of the radial-to-femoral gradient was the subject of numerous studies.[17–19] Although many potential mechanisms have been proposed, there is still no clear explanation to this date. Many authors proposed that radial vasoconstriction could alter pulse wave transmission and therefore cause the pressure gradient.[17,18,20] Other mechanisms have been proposed such as blood viscosity,[21] hand vessels vasodilation,[4,14] and blood vessel elasticity,[15] all of which could cause the phenomenon by influencing the blood flow and the pulse wave transmission. Because there is still a lack of understanding regarding the mechanisms causing the pressure gradient, studies identified risk factors that could help clarify the phenomenon. Risk factors that have been reported are the hematocrit,[21] minimal temperature,[16] CPB and clamping time,[8,20] and factors associated with radial artery diameter such as demographic data,[16,20,22] vasoactive medication,[8,20] and plasma norepinephrine levels.[8]

These various hypotheses indicate that the pathophysiology of the gradient probably is multifactorial. It is therefore essential to identify risk factors that could guide future research and help clinicians identify patients who would most benefit from femoral line insertion. However, although many studies tried to recognize such risk factors, few were identified and confirmation is still needed for most. Therefore, all these potential risk factors should be analyzed when studying central-to-peripheral pressure gradient in cardiac surgery.

So far, no study had enough patients to develop a predictive model. In addition, not all associated factors were reported in all the studies. Finally, the impact of the radial-to-femoral gradient in terms of postoperative hospitalization has not been reported. In this study, the authors investigate all these potential risk factors in the largest number of patients yet reported on this subject.

## Methods

In this retrospective study, a total of 818 consecutive adult patients issued from a transesophageal echocardiography and hemodynamic database were analyzed following approval by the Research Ethics Committee of the Montreal Heart Institute (#11-1277). This database has been previously used in other studies.[23–25] Inclusion criteria were adults of any age that underwent cardiac surgery with CPB and had both a radial and a femoral artery cannula inserted for monitoring. The data were collected with regard to the presence or absence of a radial-to-femoral pressure gradient. An electronic screenshot (Atomos, Global Pty LTD, Port Melbourne, Australia) of the hemodynamic waveforms was obtained at the beginning and whenever a radial-to-femoral arterial pressure gradient was present as shown in Figure 1.

The decision to insert a radial and/or a femoral artery catheter was left to the judgment of the attending anesthesiologist. All femoral artery catheters were inserted under ultrasound guidance. However, it is common practice for most of the anesthesiologists in the authors' institution to insert both catheters routinely in all patients.[20,26,27] Exclusion criteria were dysfunctional arterial line during the procedure and missing data from the database with regard to the gradient. The patients were classified according to the presence or absence of radial-to-femoral pressure gradient. The authors considered a significant radial-to-femoral pressure gradient to be $\geq 25$ mmHg in systolic pressure and/or $\geq 10$ mmHg in mean arterial blood pressure for a minimum of 5 minutes.[20]

Data regarding the following preoperative variables was collected: Parsonnet and the EuroSCORE II, demographics (age, gender, height, weight, body mass index [BMI, kg/m$^2$], and body surface area [BSA, m$^2$]), comorbidities (hypertension, diabetes, unstable angina, myocardial infarction, left ventricular [LV] dilation, and LV hypertrophy), and preoperative medication. Fluid balance was defined as the total amount of fluid intake (crystalloids, medications, blood products, and

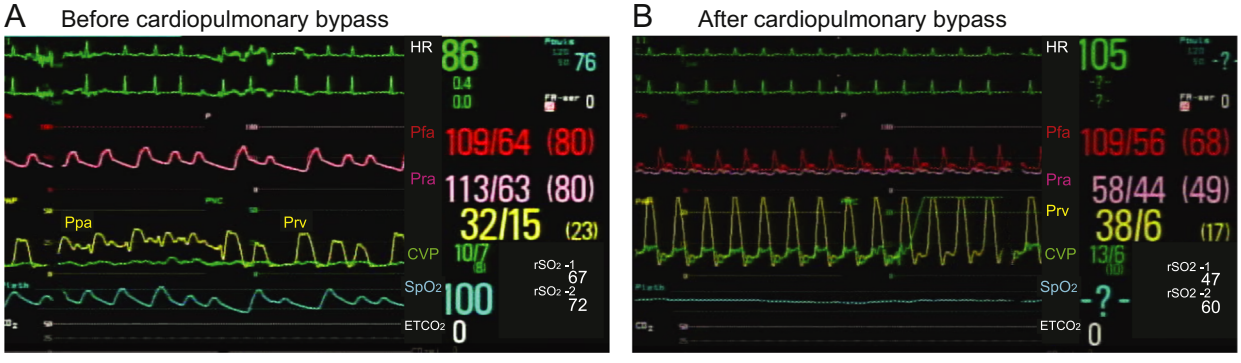


Fig 1. Screenshot of hemodynamic waveforms of a 58-year-old woman undergoing aortic surgery (A) before and (B) after CPB. A significant gradient between the radial artery pressure (Pra) and the femoral artery pressure (Pfa) appeared after CPB. Note the change in right ventricular pressure waveform (Prv) and central venous pressure (CVP) suggestive of right ventricular dysfunction associated with reduced regional oxygen saturation ($rSO_2$). The patient was receiving inhaled agents hence the end-tidal carbon dioxide ($ETCO_2$) of 0. Ppa, pulmonary artery pressure; $SpO_2$, arterial pulse oxygen saturation.

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