Intraindividual Variability and Association of Human Collateral Supply to Different Arterial Regions

Michael Stoller, MD, and Christian Seiler, MD*

The intraindividual variability and association of human collateral functional supply to different arterial regions is unknown. The primary study end point was collateral flow index (CFI) as obtained in the coronary artery (CA), renal artery (RA), left superficial femoral artery (SFA), and left subclavian artery (SCA) of the same individual. CFI is the ratio between simultaneously recorded mean arterial occlusive pressure divided by mean aortic pressure both subtracted by mean central venous pressure. In 100 patients admitted for diagnostic coronary angiography, CFI was assessed in 3 arterial regions (CA, RA, and SFA), 13 patients underwent CFI measurements in all 4 territories. By quantitative coronary angiography, 82 patients had a stenosis <50% in diameter in the CA who underwent CFI measurement. CFI in the CA, RA, left SFA, and left SCA region amounted to 0.110 ± 0.093, 0.119 ± 0.082, 0.512 ± 0.147, and 0.563 ± 0.155, respectively (p <0.0001). There was a direct and linear correlation between CA and SFA CFI: CFI_SFA = 0.47 + 0.47CFI_CA (r^2 = 0.05; p = 0.0259). In patients with CFI values in all 4 arterial regions, an inverse linear relation between left SFA and left SCA CFI was observed: CFI_SCA = 0.91−0.67CFI_SFA (r^2 = 0.36; p = 0.0305). In conclusion, intraindividual, preexistent collateral function is widely varying between different arterial supply areas. On average, collateral flow ranges from approximately 12% in comparison to flow during arterial patency in the coronary and renal circulation to over 50% in the left SFA and left SCA, that is, circle of Willi's territory. CA and SFA CFIs are directly related to each other. **(Am J Cardiol 2016;117:685−690)**

Of all vascular regions, the collateral circulation of the heart is the most extensively studied since the early studies by Fulton.[1,2] Although interest in the cerebral collateral circulation is gaining momentum fast,[3] its routine assessment is currently still occurring only by angiographic scoring.[4] This is surprising given the potential insight into the circle of Willis' function and the pial collateral circulation during interventional cervical or cerebral occlusive pressure measurements. Collateral pathways of the lower extremities have been described previously,[5] typically in the presence of severe atherosclerotic involvement. The renal collateral circulation has hitherto been subjected to systematic research only in experimental studies,[6,7] whereas data in humans are sparse and limited to angiographic assessment.[6,8,9] The innate human collateral function in different vascular regions is of interest, because an ischemic event in one of them constitutes a risk for a subsequent event in a remote area.[10,11] On a patient level, this relates to the intraindividual , as opposed to the interindividual distribution of the collateral network. Although the interindividual distribution of innate human collateral function is varying widely,[12−16] the variability and association of the collateral function between different vascular regions in humans has not been investigated so far.

Methods

This was a prospective observational study in 100 patients who underwent coronary angiography for diagnostic purposes in the context of chest pain. The primary study end point was pressure-derived collateral flow index (CFI; see the following for calculation) as obtained from the same patient in 3 to 4 different systemic arterial regions (Figure 1): coronary artery (CA), renal artery (RA), left superficial femoral artery (SFA), and in 13 patients, left subclavian artery (SCA). The secondary study end point was oxygen saturation as obtained in the ipsilateral renal vein at the end of a 6-minute RA balloon occlusion (see the following). Criteria for study inclusion were age >18 years, written informed consent to participate in the study, and 0- to 3-vessel chronic stable coronary artery disease. Exclusion criteria were acute coronary syndrome, previous myocardial infarction in the vascular region undergoing CFI measurement, more than double renal arterial supply, severe hepatic, or renal failure (creatinine clearance <15 ml/min/1.73 m^2). The study was approved by the ethics committee of the Kanton of Bern, Switzerland, and all patients gave written informed consent to participate.

Patients underwent left heart catheterization and coronary angiography for diagnostic purposes from the right femoral artery approach through a 65-cm long 8F introducer sheath.

Department of Cardiology, University Hospital, Bern, Switzerland. Manuscript received August 3, 2015; revised manuscript received and accepted November 10, 2015.

ClinicalTrials.gov Identifier: NCT002063347.

This work was supported by grants #3200B_141030/1 from the Swiss National Science Foundation for research to Dr. Seiler and #14B055 from the Novartis Foundation for Medical-Biological Research to Drs. Stoller and Seiler.

See page 690 for disclosure information.

*Corresponding author: Tel: (+41) 31-632-36-93; fax: (+41) 31-632-42-99.

E-mail address: christian.seiler@insel.ch (C. Seiler).

0002-9149/15/$ - see front matter
http://dx.doi.org/10.1016/j.amjcard.2015.11.026

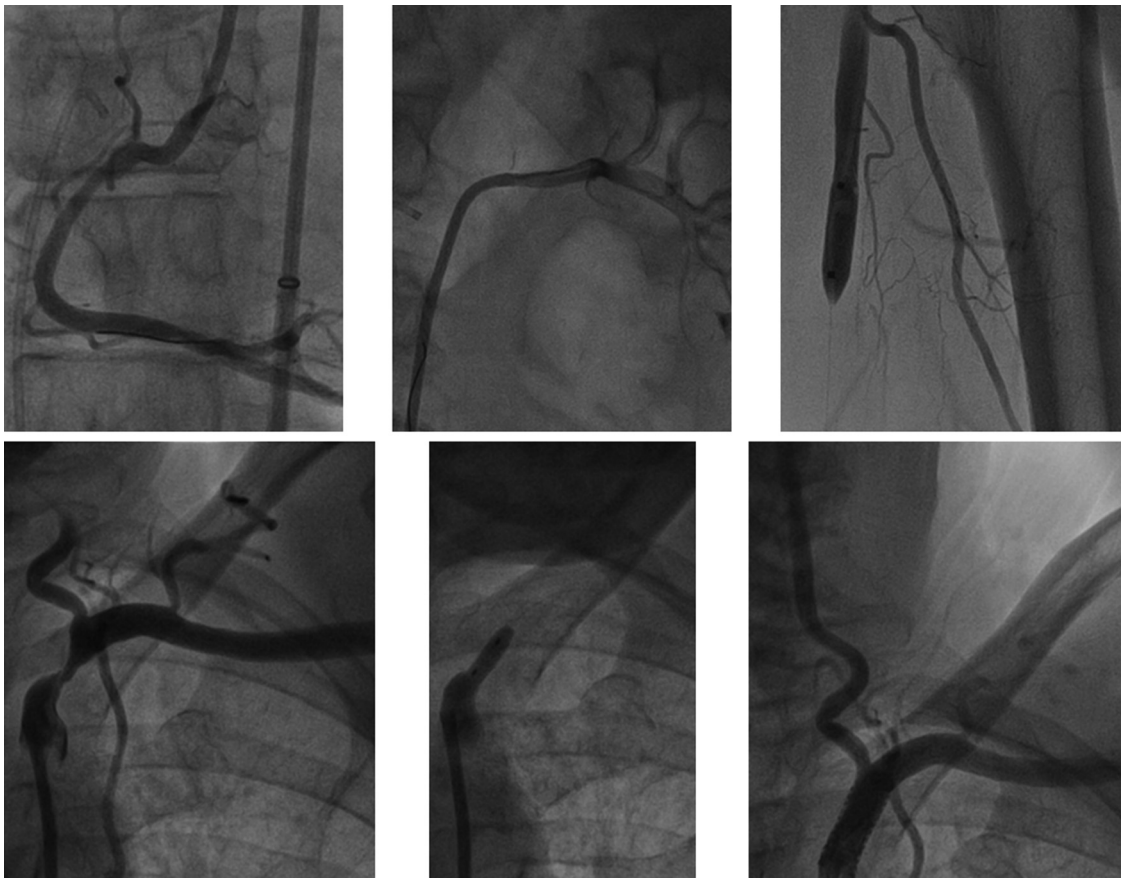

Figure 1. Angiographic images as taken from the same patient of the 4 arterial territories undergoing CFI measurements: Right CA *(left upper panel)*, left renal artery *(middle upper panel)*, left superficial artery during balloon occlusion *(right upper panel)*; the lower panels show left SCA angiograms before *(left lower panel)*, during *(middle lower panel),* and after stenting *(right lower panel)* of a tight stenosis, which caused a subclavian steal syndrome with limited vertebral artery flow *(left lower panel)* before treatment of the stenosis.

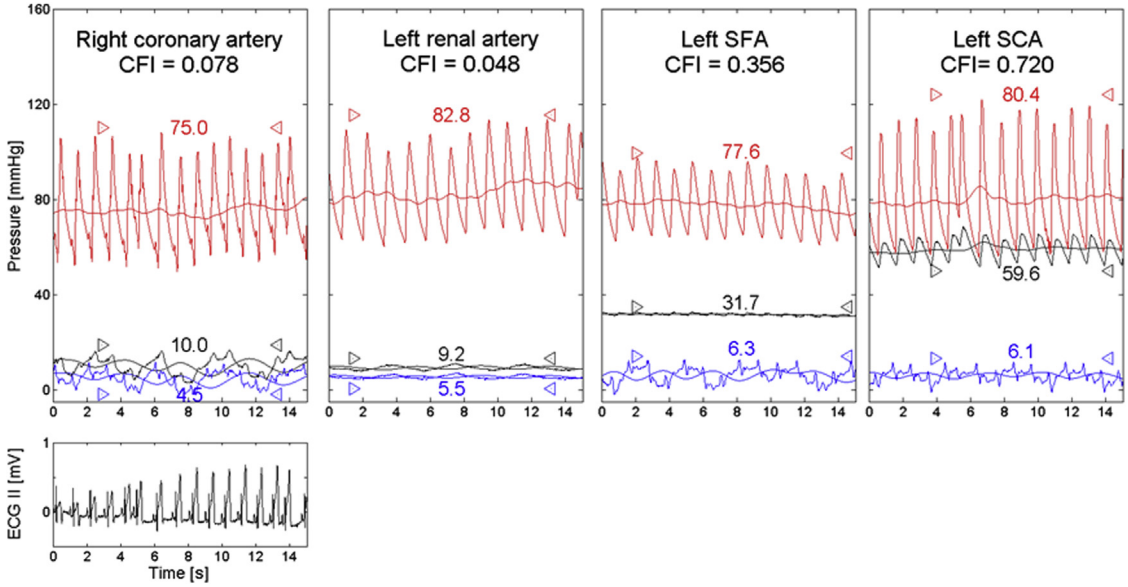

Figure 2. CFI measurements from the same patient as in Figure 1 showing simultaneous recordings during proximal arterial balloon occlusion of phasic and mean aortic pressure (P_{ao}, mm Hg; *black lines*), arterial occlusive pressure (P_{occl}, mm Hg; *red lines*) and CVP, mm Hg *(blue lines)*. In case of right CA CFI measurement, one ECG lead showing increasing ST-segment elevations is simultaneously recorded. CFI is calculated as $(P_{occl}-CVP)/(P_{ao}-CVP)$. Pressure scale is from 0 to 120 mm Hg; time scale is in seconds. ECG = electrocardiogram.