and video 2 of the supplementary material). The patient was transferred to the intensive care unit, but extubation was not possible because of excessive pulmonary blood flow. A new catheterization was carried out 12 days after the first, and growth of both pulmonary branches was observed (Figure C and video 3 of the supplementary material). The collaterals were successfully embolized with Interlock coils (Boston), thereby allowing extubation and hospital discharge at 20 days following the second procedure. At 6 months of follow-up, the patient was asymptomatic, with arterial oxygen saturation at 82%, and awaiting a partial cavopulmonary shunt.

Treatment of pulmonary atresia with a ventricular septal defect, hypoplastic pulmonary arteries, and major aortopulmonary collateral vessels remains a challenge. The conventional surgical approach is a systemic-to-pulmonary artery shunt, which, in low-weight neonates, may imply major complications, such as shunt obstruction or thrombosis, pulmonary hyperflow, and infection.[1] Another surgical option is partial correction, which requires the use of extracorporeal circulation and can lead to greater morbidity and mortality.

In the cardiac catheterization laboratory, radiofrequency perforation of the pulmonary valve with stent implantation in the right ventricular outflow tract has become a valid option for treating patients with pulmonary atresia, although it is associated with a need for follow-up surgery in 33% to 75% of patients.[3] The most commonly described complications related to this technique are perforation of the cardiac wall and fracture or dislocation of the stent, among others.[4]

The hybrid procedure approach averts the need for extracorporeal circulation and is safer and faster than an interventional procedure, as it allows adequate anatomical inspection and enables the cardiovascular surgeon to act promptly if there are incidents. Other advantages are a shorter fluoroscopy time and no weight limitations in neonatal patients.[5] Therefore, it can be concluded that valve perforation with stent implantation through the transventricular route using a median sternotomy is an effective palliative technique, especially for low-weight premature infants, that offers results similar to those of other therapeutic strategies with lower in-hospital morbidity and mortality rates and satisfactory long-term survival (Table, supplementary material). This technique achieves adequate development of the pulmonary arterial tree, so that corrective surgery can be performed in a second stage when the patient is older and has gained weight.[6]

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found in the online version available at doi:10.1016/j.rec.2017.10.032.

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Volumetric Quantification of Coronary Flow by Using a Monorail Infusion Catheter: Initial Experience

Cuantificación volumétrica de flujo coronario mediante catéter de infusión monorraíl: experiencia inicial

To the Editor,

Absolute volumetric coronary blood flow can now be measured invasively by thermodilution due to a new purposely designed monorail microcatheter that allows homogeneous and continuous mixing of room-temperature saline solution with intracoronary blood.[1] This microcatheter (Rayflow; Hexacath) has 4 openings at its distal end, and the terminal distal opening is occluded by the guidewire, permitting homogeneous infusion.[1] The intracoronary guidewire has a temperature sensor linked to dedicated software (RadiView; Abbott), allowing thermodilution-based measurements of the maximal volume of intracoronary blood per unit of time, according to the formula:

$$Qb = 1.08Ti/TQi$$

where T_i is the temperature of the infused saline exiting the infusion catheter, T is the temperature of the blood-saline mixture in the distal portion of the coronary artery, and Q_i is the preset saline infusion rate through the microcatheter (Figure).[1] This procedure can yield quantitative estimates not only of the maximal coronary blood flow (MCF), but also of the corresponding minimal microvascular resistance in the irrigated territory, since this is the ratio of coronary pressure to coronary blood flow, both of which are known.

We prospectively recruited 14 patients in whom quantitative coronary angiography revealed no significant coronary lesions (stenosis < 30% of the luminal diameter). In most study

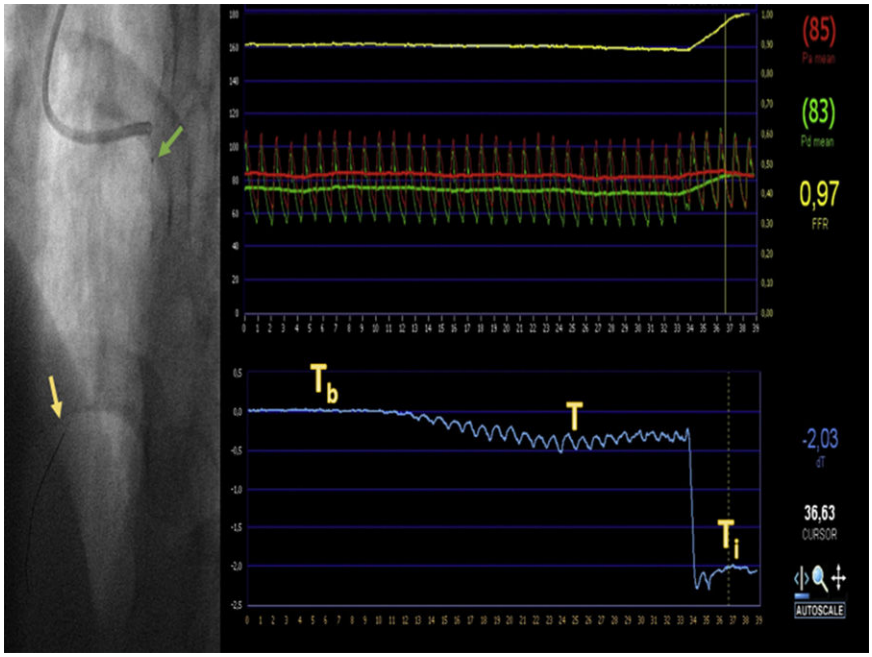

Figure. Example measurement of absolute volumetric coronary blood flow. An intracoronary guidewire with a dual pressure and temperature sensor is passed through a guide catheter into the distal segment of the anterior descending coronary artery (yellow arrow). The Rayflow microcatheter is threaded over this guide catheter and advanced into the proximal segment of the artery (green arrow). After connecting the proximal microcatheter tip to an infusion pump, a room-temperature saline solution is infused into the coronary artery at a preset flow rate. The screen displays a real-time readout of the baseline temperature (T_b) and the infusion-induced gradual decrease to a new stable temperature (T). Once the intracoronary temperature stabilizes, the guidewire is withdrawn until the temperature sensor is positioned at the microcatheter tip in order to measure the infusion temperature (T_i). This allows quantitative measurement of maximal volumetric coronary blood flow in the artery according to the formula $Q_b = 1.08\ T_i/T\ Q_i$, where Q_i is the preset saline infusion rate. Aortic pressure (red trace) and distal coronary pressure (green trace) are monitored simultaneously with the temperature recording; this allows quantitative estimation of fractional flow reserve (yellow trace) and minimal microvascular resistance in the irrigated territory using the formula $R = P_d/Q_b$, where P_d is the distal intracoronary pressure and Q_b is the absolute coronary blood flow.

participants (11 patients), the indication for coronary angiography was stable angina and a positive or inconclusive exercise treadmill test (6 and 5 patients, respectively). The other 3 patients had ventricular dysfunction with a suspected ischemic etiology. After obtaining informed consent, we carried out an intracoronary evaluation of anterior descending artery function in all patients. A guidewire with a dual temperature and pressure sensor (Certus, Abbot Vascular) was passed through a 6-Fr guide catheter. Physiological parameters were obtained at baseline and after induction of maximal hyperemic flow by perfusion of adenosine (140 μg/kg/min) through the peripheral antecubital vein. The microcatheter was then advanced over the pressure/temperature sensor-tipped guidewire to position its distal extreme in a proximal segment of the artery. Using an infusion pump, saline solution at room temperature was infused through the microcatheter at a rate of 18 mL/min. Once a stable drop in temperature was obtained, the guidewire with the temperature sensor was withdrawn to the microcatheter tip in order to measure the infusion temperature (Figure). All data collection was automated, and data were stored and subsequently analyzed with the specific RadiView software (Abbott).

The mean age of the 14 patients was 66 ± 8 years, and 5 (36%) were women. Of the patients, 3 (21%) had diabetes, 10 (71%) hypertension, and 5 (36%) dyslipidemia; 2 (14%) were smokers. The mean interval from guide catheter introduction to completing all measurements was 8.6 ± 6 min. The mean time from starting infusion to achieving a stable temperature decrease was 7.6 s. The median MCF was 153 mL/min [interquartile range, 114-179 mL/min], with a median microvascular resistance of 619 Wood units [396-689 WU] (Table). Median fractional flow reserve showed a tendency to lower values after saline infusion than after adenosine infusion (0.84 vs 0.89; P = .09). In 2 patients (14%), saline and adenosine infusion yielded discrepant assessments of lesion functional significance (with the cutoff set at ≤ 0.80). Among the participants, 1 patient

Table
Intracoronary Hemodynamic Parameters Obtained

Patient	Pd/Pa	CFR	IMR	FFRa	FFRs	AF (mL/min)	MMR (WU)
1	0.98	2.0	18	0.93	0.93	159	605
2	0.93	2.6	14	0.89	0.78	112	830
3	0.96	2.9	40	0.86	0.82	117	823
4	0.98	1.7	25	0.93	0.84	160	351
5	0.94	3.2	11	0.91	0.83	180	444
6	0.97	4.4	20	0.99	0.99	130	632
7	0.94	1.3	34	0.96	0.88	108	667
8	0.96	2.5	10	0.86	0.83	176	464
9	0.91	1.2	13	0.91	0.92	201	411
10	0.96	2.1	28	0.76	0.81	115	653
11	0.97	5.1	9	0.84	0.84	190	253
12	0.96	3.6	12	0.89	0.81	179	266
13	0.90	1.4	28	0.89	0.87	101	718
14	0.98	4.4	15	0.88	0.80	147	675
Mean	0.95	2.7	20	0.88	0.86	148	557

AF, absolute coronary flow; CFR, coronary flow reserve; FFRa, fractional flow reserve induced with adenosine; FFRs, fractional flow reserve induced by intracoronary saline infusion; IMR, index of microcirculatory resistance; MMR, minimal microvascular resistance; Pd/Pa, ratio of mean intracoronary pressure to mean aortic pressure.

developed a transitory acute arterial occlusion that resolved spontaneously with no complications.[2]

Our study confirms the ability of thermodilution with continuous infusion of room-temperature saline to quantify functional parameters of intracoronary blood flow in a population of patients with no angiographically significant coronary lesions. These quantified variables are obtained by the infusion of saline solution through a specially designed catheter. This new method is the first to allow quantitative measurement of MCF and minimal vascular resistance. A recent study confirmed that intra-arterial infusion of room-temperature saline solution can induce vasodilation in the absence of adenosine.[3] However, until now there were no published data on MCF and minimal microvascular resistance in human patients. Further studies are needed to determine the normal values for these parameters and the implications of their alteration in different disease settings.

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Pulse Wave Velocity and Central Blood Pressure: Normal and Reference Values in Older People in Spain

Velocidad de la onda de pulso y presión arterial central: valores normales y de referencia en personas mayores en España

To the Editor,

There is growing interest in pulse wave velocity (PWV) and central aortic systolic pressure (CASP) as cardiovascular disease risk markers that go beyond conventional (brachial) blood pressure (BP).[1,2] Pulse wave velocity estimates arterial stiffness, and CASP is representative of the "true" BP in major organs. Both parameters can now be reliably estimated through brachial cuff-based oscillometric methods[3]; however, their clinical usefulness is limited by the scarcity of normative data.

Two major international studies have reported pooled normative PWV and CASP values,[4,5] but neither included Spanish data. Therefore, this is the first study to report normative values for these parameters in older adults in Spain.

Data were taken from 1824 community-dwelling adults aged ≥ 65 years belonging to the third wave of the Seniors-ENRICA study, a cohort set up in Spain from 2008 to 2010, which has had CASP and PWV data since 2014-2015.[6] Participants gave written consent, and the study was approved by the *La Paz* Hospital Clinical Research Ethics Committee.

Fasting lipids and glucose were analyzed in a central laboratory. Participants reported diagnosed cardiovascular disease. Diabetes was defined as glucose ≥ 126 mg/dL, previous diagnosis, or current treatment; dyslipidemia as total cholesterol ≥ 240 mg/dL, low-density lipoprotein cholesterol ≥ 160 mg/dL, high-density lipoprotein cholesterol ≤ 40 mg/dL (men) and ≤ 50 mg/dL (women), triglycerides ≥ 250 mg/dL, previous diagnosis, or current treatment.

Brachial BP, CASP, and PWV were measured under standardized conditions with a validated oscillometric device (Mobil-O-Graph 24 h PWA, I.E.M., Stolberg, Germany; Mediscan, Spain).[3] The mean of the last 3 of 4 measurements was used for analysis. Hypertension was defined as mean brachial systolic BP ≥ 140 mmHg, diastolic BP ≥ 90 mmHg, or current treatment.

Of the 1824 participants, 1544 had valid, complete data on the study variables (Figure of the supplementary material). Of these 1544, 946 were excluded for being treated for hypertension or dyslipidemia, having diabetes, or previous cardiovascular disease.[4,5] Of the 598 remaining individuals, 263 were normotensive, with 129 without cardiovascular risk factors (untreated dyslipidemia or current smoking) forming the "normal population", and 134 with other cardiovascular risk factors. These latter 134 participants plus the untreated hypertensive patients without (n = 180) or with (n = 155) other cardiovascular risk factors formed the "reference population".

Normative data are expressed in percentiles, stratified by age and sex. Analyses were performed using the SPSS v.21.

The participants mean age was 72.9 years (57.7%, women) (Table 1). Mean body mass index, glucose, lipids, and BP were higher in the reference population. PWV and CASP distributions were nonnormal, asymmetric to the right, and with moderate kurtosis. For the total population, median PWV was 10.2 m/s and was higher in the reference than in the normal population (10.3 vs 10.1; $P = .042$ with Mann-Whitney test and $< .001$ with Wald-Wolfowitz test), in women (10.3 vs 10.1 in men; $P = .049$), and in participants aged ≥ 75 years (11.6 vs 10.0 in < 75 years; $p < .001$) (Table 2). Median CASP was 116.6 mmHg, and was higher in the reference population ($P < .001$ with both nonparametric tests); this pattern remained when the analysis was stratified by age and sex. The concordance between measurements was close to good (intraclass correlation coefficients in the 3 populations for both PWV and CASP: ∼0.61-0.67).

Central aortic systolic pressure values were lower in our study (median ∼117 mmHg) than in older individuals from a worldwide database (median ∼126 mmHg).[5] Although the international pooling used tonometry-based techniques, oscillometric methods yield only smaller CASP values (∼0.6 mmHg).[3] Thus, we suggest that, despite methodological standardization across studies, pooling normal/reference data does not necessarily apply to a specific country. From a physiological viewpoint, for a given brachial pulse pressure, the lower the central pulse pressure the more beneficial the effect on the cardiovascular system, because the heart and the aorta would deal with a lower pulsatile load.[1]