A novel method of measuring pulmonary vascular resistance with XMR

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Introduction

Pulmonary hypertension is assessed by invasive measurement of pulmonary vascular resistance (PVR). The Fick principle, used to measure pulmonary blood flow, has limitations, particularly in patients with congenital heart disease. Phase contrast magnetic resonance (MR) has been shown to provide accurate quantification of blood flow. We have set up a programme of MR guided diagnostic cardiac catheterisation, which allows simultaneous acquisition of invasive pressures and MR flow data and thus calculation of PVR.

Purpose

To demonstrate the feasibility of using a combination of invasive pressure and MR flow measurements to calculate PVR. In addition, to compare PVR calculated using this new technique and the traditional Fick technique.

Methods

20 patients underwent cardiac catheterization, in an MR interventional suite (1·5T Intera I/T MRI scanner, Philips, The Netherlands) with x-ray back-up (BV Pulsera cardiac x-ray unit, Philips, Best, The Netherlands). This allowed simultaneous acquisition of MR flow data and invasive pressure measurements and thus calculation of PVR. In 15 patients data was acquired at baseline (condition 1) at 20ppm nitric oxide (condition 2) and at 20ppm nitric oxide + 100% oxygen (condition 3). In 10 of these patients Fick and MR quantification of pulmonary blood flow was carried out allowing comparison of these methods. A distensible flow phantom was used to validate phase contrast MR. X-ray dose was recorded in all study subjects and compared to x-ray dose in age and procedure matched controls who underwent treatment in our traditional catheterization laboratory.

Results

Simultaneous pressure and flow data were obtained in all 20 patients. In 7 patients catheterization of the pulmonary artery was achieved under MR guidance alone. The median baseline PVR for all 20 patients calculated using phase contrast MR flow data was 3.2 WU.m^2. In the 15 patients in whom the response to vasodilators was assessed the baseline PVR was 3.3 WU.m^2. At condition 2, the median PVR fell to 3.1 WU.m^2 and at condition 3 the median PVR fell to 3.0 WU.m^2.

The correlation coefficient between flow quantified using phase contrast MR and using a graduated cylinder and stopwatch method was 0.99. The bias was negligible (-0.02 l/min), an upper level of agreement was 0.26 l/min and a lower level of agreement was -0.30 l/min.

In the 10 patients in whom Fick and MR were compared the correlation coefficient was 0.98 and Bland Altman analysis revealed a bias of 2.3%, and limits of agreement of 45.1% to -46.7% at condition 1. At condition 2 there was poorer agreement (bias was 2.7%, and the limits of agreement were 77.3 to -71.9%) and correlation (r=0.92). At condition 3 there was very poor agreement (bias was 34% and the limits of agreement were 129.9% to -60.6%) and only moderate correlation (r=0.83).

There was a significant difference ($p<0.05$) between the mean x-ray dose received by patients undergoing XMR guided cardiac catheterization (median 0.67 Gycm^2,) and control subjects (median 27.3 Gycm^2).

Conclusion

We have demonstrated the feasibility of using simultaneous invasive pressure measurements and MR flow data to measure PVR in humans. The results suggest that this technique is more accurate than invasive oximetry and has the benefit of reduced x-ray exposure. In 7 patients catheterisation was done wholly under MR guidance. Before cardiac catheterization can be performed entirely under MR guidance in all cases, improved catheter visualization and the provision of MR compatible guide wires and high torque catheters is required. Once these are addressed, these procedures could be carried out in a standard MR suite with minor operations sterility. Furthermore new velocity encoded imaging techniques will increase the speed and accuracy of this method. We plan to show the benefits of this technique in a larger group of patients. This should make MR guidance the method of choice for invasive PVR quantification