Pulmonary Perfusion after Endovascular Stenting of Pulmonary Artery Stenosis

Wim J.G. Oyen, Anton M. van Oort, Ronald B. Tanke, Gert-Jan van Mill, Wim R.M. Aengevaeren and Frans H.M. Corstens

Departments of Nuclear Medicine and Cardiology, University Hospital Nijmegen; and Children's Heart Center, Nijmegen, The Netherlands

Pulmonary artery stenosis is a well-known condition after surgical correction of tetralogy of Fallot. Endovascular stenting of the stenosis is a new technique for correction without surgical intervention. Objective evaluation of the procedure, however, is often hampered by moderate or severe pulmonary valve insufficiency. This disadvantage does not apply to ^{99m}Tc-macroaggregates of albumin (MAA) scintigraphy of the lungs. Moreover, quantification can be performed relatively easy. **Methods:** Seven patients with surgically corrected tetralogy of Fallot (4 men, 3 women, mean age 15.7 yr, range 5–24 yr) were studied. The mean diameter decrement of a pulmonary artery was 69% ± 8.7%. Before and after stenting, relative uptake in the left and right lung was assessed after injection of 37–55 MBq ^{99m}Tc-MAA. Three patients were studied twice after stenting. **Results:** In all patients, perfusion of the affected lung increased significantly: before 22.7% ± 10.8%, after 38.6% ± 12.3% ($p < 0.0001$). All patients claimed clinical improvement of their condition after stenting. The perfusion gain did not correlate with the prestenting diameter decrement or with the pressure gradient over the stenosis. Lung uptake in the patients studied twice after stenting was similar between the initial and poststenting study (≤2% difference). **Conclusion:** Quantitative ^{99m}Tc-MAA lung imaging is a noninvasive technique without patient discomfort that objectively measures the effect of stenting pulmonary artery stenosis. The final outcome of stenting with regard to increment of pulmonary blood flow is not predicted by the severity of the stenosis or the pressure gradient over the stenosis.

Key Words: lung scintigraphy; technetium-99m-MAA; tetralogy of Fallot; endovascular stent; pulmonary artery stenosis; angioplasty

J Nucl Med 1995; 36:2006–2008

Tetralogy of Fallot is a congenital heart condition complicated by hypoplasia of the pulmonary artery, necessitating aortopulmonary shunt surgery in infancy. Total correction of the cardiac and vascular abnormalities is, in most cases, completed with surgical patch angioplasty of the pulmonary artery at the site of the congenital stenosis or around the discontinuance of the shunt. At the angioplasty site, however, restenosis can occur. Blood flow in the affected lung (segment) may be severely decreased due to this pulmonary restenosis. Repeat surgery in a scarred region is difficult with the inherent risk of relapsing restenosis. Balloon angioplasty results in initial dilatation. After balloon withdrawal, however, immediate recurrence of the stenosis often occurs. A new technique, endovascular stenting of the pulmonary artery stenosis, postpones the need for surgical intervention or at least facilitates the procedure by making peripheral angioplasty superfluous when homograft implantation is indicated (*1*). It is often difficult, however, to assess objectively and quantitatively the benefit of a stenting procedure due to moderate or severe pulmonary valve insufficiency. This study reports the use of perfusion lung scintigraphy with ^{99m}Tc macroaggregates of albumin (MAA) to evaluate improvement in local pulmonary perfusion.

METHODS

Patients

Seven patients (4 men, 3 women; mean age 15.7 yr, range 5 to 24 yr) with surgically corrected tetralogy of Fallot, pulmonary valve insufficiency and pulmonary artery stenosis were studied. The stenoses (three right, four left) were located at the proximal part of the pulmonary branches just beyond the pulmonary trunk (at the site of the, now closed, shunt angioplasty) or at the origin of the lower lobe branches. Stenosis severity (related to the diameter of the artery just beyond the stenosis) as assessed by right-sided cardiac catheterization was 69% ± 8.7% (mean ± s.d.) with a range of 58%–83%. The mean pressure gradient over the stenosis was 33.0 mmHg ± 20.5 mmHg (mean ± s.d.) with a range of 7 to 62 mmHg. Stenosis severity did not correlate with the pressure gradient ($R^2 = 0.0005$, $p = 0.96$), most probably due to the presence of pulmonary valve insufficiency. Clinically, the stenosis resulted in complaints of persisting tiredness. The stenosis was resolved by using a Strecker stent (Medi-Tech) in one patient or Palmaz (Johnson and Johnson Interventional Systems, Sommerville, NJ) stents with diameters ranging from 12 to 18 mm in the other patients.

Imaging Protocol

Before and after stenting multiview static imaging of pulmonary perfusion was performed starting 3 min after intravenous injection of 37–55 MBq ^{99m}Tc-MAA. In six patients, the interval between

Received Jan. 31, 1995; revision accepted Jul. 5, 1995.

For correspondence or reprints contact: Wim J.G. Oyen, MD, University Hospital Nijmegen, Department of Nuclear Medicine, P.O. Box 9101, 6500 HB Nijmegen, The Netherlands.

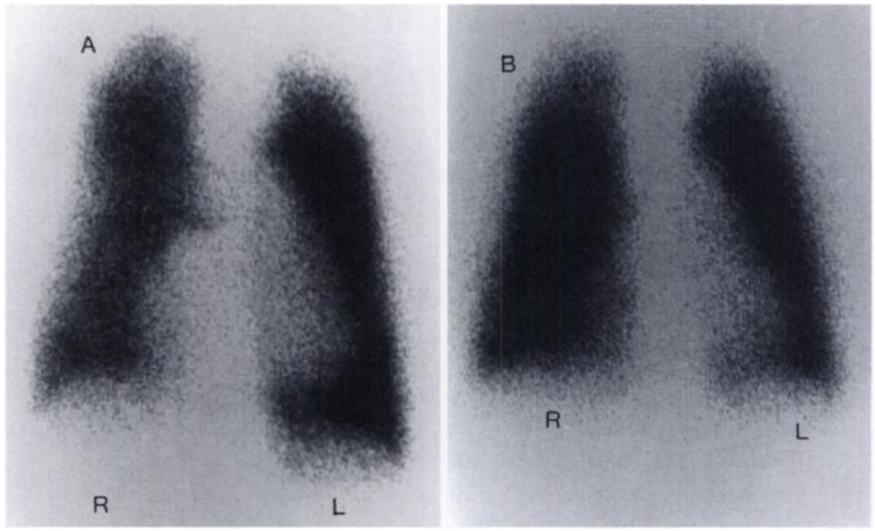

FIGURE 1. (A) Before stenting, relative perfusion of the right lung is 38% of total lung perfusion. (B) After stenting, relative perfusion of right lung increased to 60% of total lung perfusion (58% relative increase).

imaging and the stenting procedure varied from 2 days to 3 mo, depending on whether diagnostic heart catheterization was performed between scintigraphy and stenting procedure. In one patient, the interval between the first scan and the stenting procedure was 2 yr, due to considerable patient delay. In three patients, the attending cardiologist ordered an additional poststenting pulmonary perfusion study to check the patency of the stent 3 to 6 mo after the first scintigraphic study. Patients were always injected in supine position. Anterior and posterior images of the chest were recorded using a gamma camera equipped with a low-energy, parallel-hole collimator. For both views, 350,000 counts were digitally recorded in a 256 × 256 matrix. The images were analyzed by drawing regions of interest over the left and right lungs. The percent uptake in the left and right lungs was derived from the geometric mean of the anterior and posterior counts.

Statistics

The results were analyzed using Student's t-test and linear regression analysis.

RESULTS

All patients claimed subjective improvement in their clinical condition after the procedure, especially a decrease in tiredness. Figure 1 depicts perfusion scintigrams before and after stenting. In all patients, perfusion in the affected lung increased after stenting (Fig. 2). Stenting significantly improved perfusion in the affected lung: relative perfusion before stenting 22.7% ± 10.8%, after stenting 38.6% ± 12.3% (mean ± s.d., $p < 0.0001$, 95% confidence interval of the difference 11.3%–20.4%). The relative perfusion in the affected lung before and after stenting correlated significantly ($R^2 = 0.84$, $p < 0.05$). Perfusion improvement in the affected lung did not correlate with the pressure gradient over the stenosis ($R^2 = 0.14$, $p = 0.41$) or with the degree of stenosis ($R^2 = 0.02$, $p = 0.75$).

Additional poststenting perfusion studies in three patients were not different from the initial study: relative poststenting perfusion in the affected lung was 30% versus 28%, 23% versus 22%, and 33% versus 31%, respectively.

DISCUSSION

Correction of tetralogy of Fallot is often complicated by a hemodynamically important residual pulmonary valve insufficiency. In some cases, this is aggravated by development of pulmonary branch stenosis. Treatment of the branch stenosis decreases the hemodynamical importance of the pulmonary valve insufficiency. With the decrement of hemodynamical relevance, the need for pulmonary valve homograft implantation is postponed. Postponing homograft implantation in childhood is of great clinical importance, since calcification and degeneration of the graft necessitates additional surgery within 5 yr. Quantitative perfusion imaging of the lungs allows objective assessment of the outcome of endovascular stenting of pulmonary artery stenosis. An additional advantage is reproducibility of relative perfusion estimates. Change in clinical status after the procedure is hard to assess, since it requires estimating general well-being and physical stress tolerance which are influenced by the coexisting pulmonary valve insufficiency. During cardiac catheterization, which is of course necessary

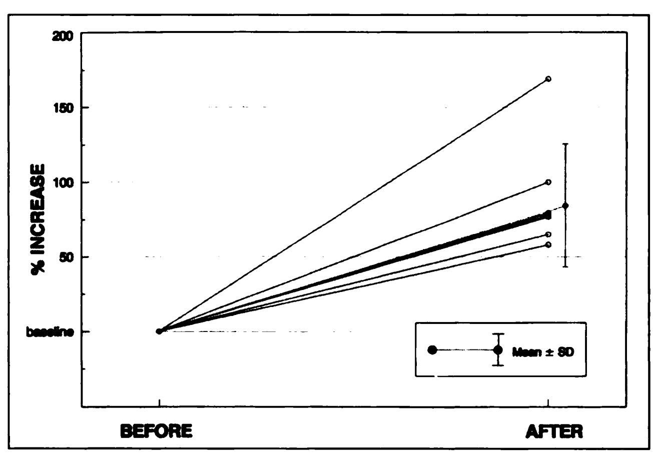

FIGURE 2. Improved pulmonary flow in the affected lung after endovascular stenting.

for anatomic assessment of the stenosis and stent placement, it is impossible to estimate the perfusion increase in the affected lung adequately due to coexisting pulmonary valve insufficiency. Catheterization evaluates structural stenosis and pressure gradient, and not the pathophysiological significance of the flow impediment (*2*). This highly invasive procedure results in a relatively high radiation burden, especially when extensive fluoroscopy is necessary, and radiographic contrast load. Perfusion lung imaging with MAA results in a low radiation burden (1–1.5 mSv) (*3*), is noninvasive and safe. When large albumin doses were used several decades ago, there were anecdotal reports on morbidity and mortality after MAA injection (*4*). Recent studies showed no or at most minor effects of the procedure on oxygen saturation (*5*). Even when an effect was measurable, there were no resulting clinical events. Saturation returned to baseline within 60 min postinjection (*5*).

CONCLUSION

Scintigraphic imaging in congenital heart disease is a well-known technique. It has been used to assess the outcome of corrective surgery in tetralogy of Fallot (*6*), right-to-left shunting (*7,8*) and other congenital anomalies (*9*). It has been largely replaced, however, by Doppler ultrasonography, subtraction angiography and MRI. Some reports also advocate perfusion lung scintigraphy to measure the relative gain in perfusion after stenting (*1,10,11*). Other clinicians, however, did not use this technique (*12*). In this study, the potential of quantitative lung imaging to objectively assess a new therapeutic procedure was investigated. Endovascular stenting of pulmonary artery branch stenosis results not only in resolution of the stenosis, as shown by radiographic angiography, but also in statistically significant improvement of pulmonary blood flow in the poststenotic lung as measured by quantitative pulmonary perfusion imaging.

REFERENCES

1. O'Laughlin MP, Slack MC, Grifka RG, Perry SB, Lock JE, Mullins CE. Implantation and intermediate-term follow-up of stents in congenital heart disease. *Circulation* 1993;88:605–614.
2. Crupi G, Anderson RH, Ho SY, Lincoln C, Buckley MJ. Complete transposition of the great arteries with intact ventricular septum and left ventricular outflow tract obstruction. Surgical management and anatomic considerations. *J Thorac Cardiovasc Surg* 1979;78:730–738.
3. Radiation dose to patients from radiopharmaceuticals. *Ann ICRP* 1987;18: 223–224.
4. Vincent WR, Goldberg SI, Desilets D. Fatality immediately following rapid infusion of macroaggregates of ^{99m}Tc-albumin (MAA) for lung scan. *Radiology* 1968;91:1181–1184.
5. Balan KK, Nagra RS, Smith ML, Critchley M. Arterial oxygen saturation in patients undergoing perfusion lung scanning with ^{99m}Tc-labeled macroaggregates of human serum albumin. *Nucl Med Commun* 1991;12:805–809.
6. Reichart B, Brunner L, Hugel W, et al. Correction of tetralogy of Fallot and its influence to oxygen transport and lung change. II. Lung changes. *Z Kardiol* 1977;66:89–94 [german].
7. Sade RM, Sloss L, Treves S, Bernhard WF, Castaneda AR. Repair of tetralogy of Fallot after aortopulmonary anastomosis. *Ann Thorac Surg* 1977;23:32–38.
8. Gates GF, Orme HW, Dore EK. Surgery of congenital heart disease assessed by radionuclide scintigraphy. *J Thorac Cardiovasc Surg* 1975;69:767–775.
9. Ruth C, Skovranek J, Samanek M. The significance of lung scintigraphy in anomalies of the pulmonary vascular bed. *Pediatr Radiol* 1975;24:21–27.
10. Rey C, Marache P, Godart F, Dupuis C. Percutaneous implantation of endoprosthesis for stenoses of branches of the pulmonary artery. *Arch Mal Coeur Vaiss* 1993;86:623–627 [french].
11. O'Laughlin MP, Perry SB, Lock JE, Mullins CE. Use of endovascular stents in congenital heart disease. *Circulation* 1991;83:1923–1939.
12. Mendelsohn AM, Bove EL, Lupinetti FM, et al. Intraoperative and percutaneous stenting of congenital pulmonary artery and vein stenosis. *Circulation* 1993;88:210–217.