Evaluation of Operability in Patients with Pulmonary Hypertension by Catheterization and Occlusion of Patent Ductus Arteriosus

By A. Actis-Dato, M.D., and A. Tarquini, M.D.

The authors describe a technic of temporary occlusion of the patent ductus arteriosus during right heart catheterization by a balloon filled with contrast medium connected to the tip of the catheter. This procedure is a valuable aid in the selection of patients with patent ductus arteriosus and severe pulmonary hypertension for operation.

As reported by various authors,1-5 surgical closure of a patent ductus arteriosus with pulmonary hypertension presents a considerable operative risk. In fact, in these cases the patent ductus may constitute a safety valve for the hypertensive lesser circulation and its surgical closure may therefore suddenly increase the pulmonary hypertension with resultant acute right ventricular strain.3

The advisability of operation in these cases always presents a difficult problem. We have studied whether better surgical evaluation could be made by studying right-sided hemodynamic changes following temporary occlusion of the ductus (by an inflatable balloon) during cardiac catheterization.

There is almost general agreement on the advisability of surgical treatment when the pulmonary pressure is moderate or slightly elevated (40 to 80 mm. Hg) though the operative risk is increased. The problem appears to be far less simple when the pulmonary hypertension is notably increased (up to 90 mm. Hg or higher).

The pulmonary hypertension may be due to (1) increased blood flow in the pulmonary bed, (2) disease of the pulmonary vessels secondary to the increased blood flow, or (3) a congenital lesion or irreversible alteration of the pulmonary vessels.1, 2, 4, 6-13 In the first instance surgical occlusion of the ductus is indicated because one thereby reduces the blood flow in the pulmonary bed. In the second case surgical occlusion may halt or even lead to reversal of the pulmonary artery pathology. One should not operate when the pulmonary hypertension is due to congenital lesions of the pulmonary vessels or when the pulmonary pressure is the same or higher than the systemic blood pressure.

Fig. 1 Catheter bearing on its tip a balloon. The syringe connected to the catheter is used to fill the balloon with contrast medium.
Preoperative differentiation of these 3 categories is difficult; therefore many surgeons base their decision on the changes in pulmonary artery pressure when the ductus is temporarily occluded during thoracotomy. If the pressure in the pulmonary artery falls or remains unchanged, the ductus is closed permanently; should the pressure increase, the ductus is left open. Other authors have performed preliminary biopsy of lung tissue in patients with patent ductus arteriosus and pulmonary hypertension to determine whether organic arteriolar lesions are present. Others have suggested pharmacodynamic tests or variation of the oxygen tension in the inspired air during cardiac catheterization to evaluate the functional component of pulmonary hypertension and the extent of its reversibility.

All methods are often unsatisfactory and there is always a serious risk in exploratory operations in these patients; we have had one death.

Moreover, the valuation of the degree of pulmonary arteriopathy on a small fragment of lung tissue may be inadequate because of irregular distribution and the difficulty in appraising its functional significance. Since September 1956 we have developed a new technic for preoperative investigation of patients with patent ductus arteriosus and pulmonary hypertension.

By this technic it is possible during right heart catheterization to occlude the ductus arteriosus temporarily and to observe the hemodynamic changes in the right side of the heart and in the systemic circulation.

METHOD

A catheter with a small balloon on its tip (fig. 1) is advanced in the usual way from the right ventricle and pulmonary artery through the

Fig. 2. Phonocardiographic recording in a case without pulmonary hypertension. The typical continuous murmur disappears after occlusion of the ductus arteriosus.

Fig. 3. The ductus arteriosus is occluded by the catheter balloon technic. By means of a second catheter introduced in the pulmonary artery (left) or in the right ventricle (right) measurement of pressures and sampling of blood are possible during the occlusion of the ductus.
ductus to the aorta. The balloon is then expanded by filling it with a contrast medium. By exerting continuous gentle traction on the catheter the ductus is occluded at its aortic end.

When the ductus is completely closed the typical murmur disappears (fig. 2).

Since pulling the catheter produced some undesirable complications, such as tricuspid insufficiency (by traction on the tricuspid valve) and ventricular premature contractions, a modification has been devised by which traction of the catheter is no longer necessary. At the present time we use a double-lumen catheter bearing 2 balloons on its tip, 3 to 4 mm. apart; on inflation of the 2 balloons the ductus is closed at both ends.

Another catheter is introduced in the pulmonary artery or right ventricle (fig. 3) to allow determination of pressure changes before, during, and after occlusion of the ductus. Changes of pulmonary blood flow are also calculated from blood samples from the pulmonary artery and the brachial artery. Observations may be made for 5 to 15 minutes.

During temporary closure of the ductus pulmonary artery and right ventricular pressures may drop, may rise, or may remain unchanged. With a drop, surgical occlusion of the ductus is definitely indicated, and with a rise it is definitely contraindicated. When there is no change we believe the operation is indicated, but pressures should be measured during effort, such as working at an ergometer while the ductus is kept closed with the balloon. If the pulmonary pressure rises under effort, we believe operation is not advisable.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>Age</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>34</td>
<td>8</td>
<td>9</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Cyanosis</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>-</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Clubbing</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Upper limb</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Lower limb</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>-</td>
<td>-</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Palpitation</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Hemoptysis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Epistaxis</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Broncho-pneum.</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+</td>
<td>-</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Physic-fitness grading (A.H.A.)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Pressures</td>
<td>Pulmonary A</td>
<td>Right</td>
<td>ventr.</td>
<td></td>
<td>Right</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with ductus patent</td>
<td>110/75</td>
<td>100/60</td>
<td>130/60</td>
<td>115/85</td>
<td>60/35</td>
<td>130/65</td>
<td>50/20</td>
<td></td>
</tr>
<tr>
<td>with ductus closed</td>
<td>120/90</td>
<td>125/70</td>
<td>150/65</td>
<td>90/80</td>
<td>-</td>
<td>130/65</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Aorta</td>
<td>110/70</td>
<td>140/90</td>
<td>95/60</td>
<td>110/70</td>
<td>120/90</td>
<td>-</td>
<td>120/70</td>
<td>-</td>
</tr>
<tr>
<td>O2 blood saturation (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>with ductus patent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.B.A.</td>
<td>83</td>
<td>95</td>
<td>91</td>
<td>92</td>
<td>94</td>
<td>95</td>
<td>96</td>
<td>-</td>
</tr>
<tr>
<td>L.B.A.</td>
<td>82</td>
<td>95</td>
<td>89</td>
<td>89</td>
<td>92</td>
<td>95</td>
<td>94</td>
<td>-</td>
</tr>
<tr>
<td>Ductus open F.A.</td>
<td>79</td>
<td>90</td>
<td>79</td>
<td>71</td>
<td>93</td>
<td>-</td>
<td>84</td>
<td>-</td>
</tr>
<tr>
<td>Ductus closed F.A.</td>
<td>82</td>
<td>95</td>
<td>90</td>
<td>92</td>
<td>94</td>
<td>95</td>
<td>95</td>
<td>95</td>
</tr>
<tr>
<td>Murmur</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>+++</td>
<td>+</td>
<td>not</td>
<td>not</td>
<td>++</td>
<td>-</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Diastolic</td>
<td>-</td>
<td>-</td>
<td>not</td>
<td>not</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Continuous</td>
<td>-</td>
<td>-</td>
<td>not</td>
<td>not</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Operation</td>
<td>None</td>
<td>Operated (Large ductus)</td>
<td>Exploratory operation (Large ductus)</td>
<td>None</td>
<td>Operated</td>
<td>-</td>
<td>Operated (Large ductus)</td>
<td>-</td>
</tr>
<tr>
<td>Results</td>
<td>-</td>
<td>Satisfactory</td>
<td>Death</td>
<td>-</td>
<td>Good</td>
<td>-</td>
<td>Good</td>
<td>-</td>
</tr>
</tbody>
</table>

OPERABILITY OF PATENT DUCTUS

Fig. 6. Case 3. Angiocardiography. Visualization of the right heart and the pulmonary artery. Note the simultaneous visualization of the descending aorta by shunting of contrast medium through the patent ductus arteriosus (reversed shunt).

RESULTS

We have studied 6 patients (table 1). In 3 pulmonary artery and right ventricular pressures dropped after occlusion of the ductus (fig. 4), and surgical closure of the ductus was followed by marked clinical improvement, which was confirmed in cases 5 and 6 by data of a second catheterization performed 1 and 2 years later. Two other patients in whom the pulmonary pressure increased after occlusion of the ductus were not operated on. The sixth patient (case 3) showed a rise of the pulmonary pressure following the occlusion of the ductus (fig. 5) and reversal of the shunt (fig. 6).

Since the patients insisted on operation, an exploratory operation was done, a sudden significant rise of the pulmonary pressure with tachycardia occurred after temporary occlusion, and the ductus was left open. Eleven days later this patient died in cardiac failure.

SUMMARY

The technic of temporary occlusion of the patent ductus arteriosus during right heart catheterization provides useful data for evaluation of patients with ductus arteriosus complicated by severe pulmonary hypertension with or without reversed shunt.

A fall in pulmonary arterial pressure following closure of the ductus with the balloon is an indication for surgical occlusion. A rise of blood pressure in the pulmonary artery following the closure of the ductus is a contraindication. When the pressure remains unchanged the patient is subjected to moderate effort; then a rise of pressure is a contraindication for the operation.

No difficulties or complications have been encountered.

SUMMARIO IN INTERLINGUA

Le technica del occlusion temporari de patente ductus arteriosus per catheterismo dextero-cardiac provide datos utile in evalutar le stato de patientes con patente ducto arterioso, complicate per sever hypertension pulmonar con o sin shuntings revertite.

Un augmento del tension pulmo-arterial post clausura del ducto per medio del ballon de catheter es un indication pro effectuar occlusion chirurgic. Un augmento del tension de sanguine pulmo-arterial es un contra-indication.

Nulle difficultates o complicationes esseva incontrate.

REFERENCES
5. Whitaker, W., Heath, D., and Brown, J.


I began to bethink my self if it might not have a circular motion, which afterwards I found true, and that the blood was thrust forth and driven out of the heart by the arteries into the habite of the body and all parts of it, by the beating of the left ventricle of the heart, as it is driven into the Lungs through the vena arteriosa by the beating of the right, and that it does return through the little veins into the vena cava, and to the right ear of the heart, as likewise out of the lungs through the aforesaid arteria venosa to the left ventricle, as we said before.

Which motion we may call circular, after the same manner that Aristotle says that the rain and the air do imitate the motion of the superiour bodies.—William Harvey. De Motu Cordis, 1628.
Evaluation of Operability in Patients with Pulmonary Hypertension by Catheterization and Occlusion of Patent Ductus Arteriosus

A. ACTIS-DATO and A. TARQUINI

_Circulation_. 1959;19:821-826
doi: 10.1161/01.CIR.19.6.821

_Circulation_ is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1959 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/19/6/821

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in _Circulation_ can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to _Circulation_ is online at:
http://circ.ahajournals.org//subscriptions/