Some Effects of Partial Pulmonary Valvectomy

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Partial pulmonary valvectomy was performed in 19 dogs. No change in pulmonary arterial pulse pressure was seen when less than one valvular cusp was removed; frequently no change was observed when an entire cusp was removed. Widening of the pulmonary arterial pulse pressure could be produced by removal of more than one cusp or by inducing pulmonary hypertension after removal of only one cusp. Observation as long as six months postoperatively revealed no evidence of right ventricular failure resulting from the operation.

Since considerable regurgitation through the pulmonary valve may result from the operation for congenital pulmonary stenosis,1 the effect upon the circulation of pulmonary valvular insufficiency is of interest. To our knowledge, this problem has not been studied experimentally, although Donovan, Hufnagel and Eastcott2 have performed operations in which the entire output of the right ventricle was shunted through the left pulmonary artery, bypassing the pulmonary valve. This procedure produced no immediate changes in cardiac function. The development of this procedure and others, such as anastomosis of the right atrium to the pulmonary artery for the treatment of congenital tricuspid atresia, makes it desirable to study the importance of the pulmonary valve in the maintenance of the normal circulation.

Materials and Methods

The work described was done upon 27 dogs whose weights ranged from 15 to 31 Kg. The animals were anesthetized with intravenous nembutal, 25 mg. per Kg. of body weight. Positive pressure respiration was instituted through an endotracheal tube, with intratracheal pressures from 4 to 8 mm. Hg. Intratracheal pressures were adjusted to the same level during cardiac pressure measurements. With the dog lying on its right side, a fourth left intercostal space incision was made. After separating the pulmonary artery and its two main branches from the aorta, a Satinsky noncrushing clamp was placed over the anterior cusp of the pulmonary artery; this cusp was then removed bloodlessly. In some instances, a portion of the right cusp was also removed or a portion of this cusp was sutured to the wall of the pulmonary artery. In two instances, the effect of inserting a glass tube through the pulmonary valve was noted.

Cournand cardiac catheters, no. 8 or 9 in size, were inserted directly through the right ventricular and pulmonary arterial walls. These were sewn in place with purse-string sutures. Simultaneous pulmonary arterial and right ventricular pressures and, in most instances, electrocardiograms were recorded on a Sanborn Poly-Viso electrocardiograph with the aid of Statham pressure transducers or Sanborn electromanometers. Pressures were recorded at paper speeds of 50 mm. per second before and after partial valvectomy. In nine animals, the effect of pulmonary hypertension, induced either by complete occlusion of one main pulmonary artery and partial occlusion of the other, or by hypoxia, was observed. In some instances, cardiac outputs were measured before and after operation by the Hamilton dye method, using T-1824. Follow-up observations were made in surviving dogs for periods up to six months. In all dogs, the amount of pulmonary valve tissue removed was verified by autopsy. Systemic arterial pressures were not measured.

Results

Satisfactory pressure measurements were obtained preoperatively and postoperatively in 19 of 27 dogs. Nine dogs survived long enough (up to six months) for observations to be made during recovery. Six of these were sacrificed. Thirteen dogs who had a complete operation died as a result of the operation; none died of right heart failure. Two animals are still alive eight months postoperatively. No evidence of right ventricular dilatation was seen immediately following the operation or at autopsy.

In 15 animals, one entire valve cusp was removed. In four of these, either an additional...
portion of the right pulmonary cusp was removed or the right cusp was partially sutured to the pulmonary arterial wall. In one animal, portions of two cusps were removed. In three animals, one-third to four-fifths only of the anterior pulmonary valve cusp was removed.

Effect of Removal of one Cusp or Less. In 18 dogs, control pulmonary arterial systolic pressures were from 14-34 mm. Hg, with a mean of 23.0. After operation, pulmonary arterial systolic pressures were 15 to 34 mm. Hg with a mean of 25.6. The mean increase of 2.6 ± 1.28 (standard error) mm. was not significant, p = >0.05. Control pulmonary arterial diastolic pressures were from 6 to 20 mm. Hg, with a mean of 10.7. After operation, the diastolic pressures were from 4 to 15 mm. Hg, with a mean of 8.8. The mean decrease of 1.94 ± 0.65 mm. is highly significant, p = <0.01. However, there was no decline in diastolic pressure in seven dogs. Control pulmonary arterial pulse pressures were from 5 to 20 mm. Hg, with a mean of 16.8 mm. The mean increase in pulse pressure of 4.55 ± 1.65 mm. is significant statistically, p = <0.02.

In 19 dogs, control right ventricular systolic pressures were from 12 to 29 mm. Hg, with a mean of 24.7. Postoperatively, the range was 11 to 41 mm., with a mean of 27.2 mm. The mean increase of 2.47 ± 1.48 mm. is not significant statistically, p = >0.05. Right ventricular diastolic pressures before operation were from -2 to 6 mm. Hg, with a mean of 12.3. After operation, pulse pressures were from 8 to 29 mm. Hg, with a mean of 16.8 mm. The mean decrease of 0.7 ± 0.58 mm. is not significant statistically, p = >0.05.

Effect of Damage to More Than One Cusp. In 3 of 4 animals in which two cusps were partially removed, the pulmonary arterial diastolic pressure fell 5 mm. Hg or more. Insertion of a glass tube through the pulmonary valve, preventing its closure, was done in two dogs. When this was done, pulmonary artery diastolic pressure fell to the level of right ventricular diastolic pressure. When the tube was removed, the pressures resumed their former relationships.

Later Effect upon Right Ventricular End-Diastolic Pressure. Restudy of eight animals after periods of two weeks to six months after operation showed no elevation of right ventricular diastolic pressure. This group included two dogs with widened pulmonary pulse pressure studied six months postoperatively. The preoperative studies of these animals had shown right ventricular diastolic pressures from -2 to 6 mm. Hg, with a mean of 3.3. Restudy showed that right ventricular diastolic pressures were from -3 to 5 mm. Hg, with a mean of 2.6 mm. The mean decrease of 0.7 ± 0.82 mm. is not significant statistically, p = >0.4. Three dogs with widened pulmonary arterial pulse pressures had also measurements of normal right atrial pressure.

Effect of Procedure on Heart Rate. The effect of the procedure upon heart rate was considered in only the nine dogs who were not subjected to acutely induced pulmonary hypertension. The latter procedure in itself often produced tachycardia of some duration. In these animals preoperative heart rates were from 118 to 167 per minute, with a mean of 148. Postoperatively heart rates were from 113 to 176, with a mean of 147. Only two animals in this group demonstrated an increase in heart rate postoperatively.

Effect of Induced Acute Pulmonary Hypertension. Acute pulmonary hypertension was induced before and after partial pulmonary valvectomy in six dogs; systolic pulmonary arterial pressures were the same or greater in the postoperative study. Pulmonary arterial systolic pressures were from 51 to 76 mm. Hg with a mean of 61 mm. in the preoperative pulmonary hypertensive period. In the postoperative pulmonary hypertensive period, pulmonary arterial systolic pressures were from 59 to 92 mm. Hg, with a mean of 71 mm. Diastolic pulmonary pressures preoperatively were from 22 to 32 mm., with a mean of
Postoperatively, diastolic pressures during hypertension were from 7 to 19 mm. with a mean of 11.7 mm. The mean decrease of 15.7 ± 2.3 mm. is highly significant statistically, \( p = <0.01 \). During preoperative pulmonary hypertension, right ventricular diastolic pressures were from 5 to 18 mm. with a mean of 11.2 mm. This is significantly different from the preoperative pulmonary arterial diastolic mean during hypertension of 27.3, with a mean difference of 16.2 ± 2.82, \( p = <0.01 \). Postoperatively, however, the right ventricular diastolic pressures during hypertension were from 5 to 18 mm. Hg, with a mean of 11.2 mm. This was not significantly different from the comparable pulmonary arterial diastolic mean pressure of 11.7, with a mean difference of 0.5 ± 0.92, \( p = >0.02 \) (fig. 1). In the same 6 animals, postoperative pulmonary arterial pressures without induced hypertension (range 5 to 15 mm., mean 10.5) were significantly higher than the comparable right ventricular diastolic pressures (range 3 to 5 mm., mean 4.5 mm.), the mean difference of 6 ± 1.69, \( p = <0.02 \).

Cardiac outputs by the Hamilton dye dilution method in 5 dogs showed no change in 1, a decrease in 3 and increase in 1. Arteriovenous oxygen differences showed no change in one dog and an increase in three. Of 9 animals, 6 showed evidence of a diminution in cardiac output postoperatively. However, because of the many variables, it is difficult to conclude that partial pulmonary valvectomy produces permanent lowering of the effective cardiac output.

**DISCUSSION**

Blount, McCord, Mueller and Swan believed that incision or partial excision of the congenitally stenotic pulmonary valve in five patients produced no significant hemodynamic alterations. Maaeke, in a personal communication to Blount, stated that experimental pulmonary insufficiency in the animal had not caused right ventricular failure in his experience. In our study, removal of a single pulmonary valve cusp was often unattended by lowering of pulmonary arterial diastolic pressure. The occurrence of more striking changes upon the induction of pulmonary hypertension suggests that the low diastolic pressure gradient between pulmonary artery and right ventricle is the reason for failure to observe more consistent changes with normal pulmonary pressure. Wiggers has stated that in aortic insufficiency, the volume of blood regurgitated through the aortic valve depends upon the pressure gradient between the aorta and left ventricle in diastole, as well as upon the size of the opening in the valve. In no animal was significant elevation of right ventricular end-diastolic pressure seen as a result of partial pulmonary valvectomy. However, the shape of the diastolic pressure-volume curve of the right ventricle indicates that the diastolic pressure in the right ventricle is a rather crude index of

![Fig. 1. Paper speed 50 mm. per second; postoperative record. A shows RV pressure of 23/1 and PA pressure of 23/0 mm. Hg after removing anterior pulmonary valve cusp. These pressures are essentially unchanged from the control. B shows pulmonary hypertension after valvectomy. RV pressure is now 57/13 and PA pressure is 61/13. Preoperatively, RV was 56/14 and PA 59/26 mm. Hg during induced pulmonary hypertension.](http://circres.ahajournals.org/content/12/1/10/f4)
right ventricular volume until rather large increases have occurred. Thus, failure to demonstrate a pressure increase does not necessarily indicate that no pulmonary regurgitation was taking place. Organic pulmonary insufficiency is rare in man. McGuire and McNamara described patients with organic pulmonary insufficiency due to rheumatic fever, syphilis and acute bacterial endocarditis. Since other valves were involved in each of these patients, it is difficult to know what effect was produced by the pulmonary insufficiency. In experimental pulmonary insufficiency longer periods of observation and observations during exercise are needed before suggesting that the pulmonary valve is not essential in the maintenance of normal circulation.

SUMMARY
Partial pulmonary valvectomy was performed in 19 dogs. Seven showed no decrease in pulmonary arterial diastolic pressure. The group as a whole showed a significant increase in pulmonary arterial pulse pressure and a lowering of pulmonary arterial diastolic pressure, but no significant change in right ventricular diastolic pressure, either acutely or in observations (up to six months). The induction of acute pulmonary hypertension after valvectomy virtually eliminated the significant pressure gradient between pulmonary artery and right ventricle during diastole, suggesting that the low diastolic pressure gradient, normally existing, is the reason for failure to observe greater change. Further study is needed to clarify the role of the pulmonary valve in maintaining normal circulation.

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