Dicrotic Pulse after Open Heart Operation

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SUMMARY
A palpable dicrotic pulse was observed in 18 patients after open heart operation, usually after prosthetic replacement for aortic regurgitation (14 of 18 patients). Two patients had a ventricular septal defect, one had aortic stenosis, and one, mitral insufficiency. The ages of the patients ranged from 9 to 63 years, but the dicrotic pulse was more prominent and persisted longer in younger patients. The dicrotic pulse usually appeared within 48 hours of operation, persisted 1 to 60 days and was always in a brachiocephalic distribution. Determinants of the dicrotic pulse include the stroke volume, the duration of systole, the distensibility of the arterial system, the peripheral reflection coefficient, and the systemic blood pressure. Impaired cardiac function with a low cardiac output was probably the most significant factor in the occurrence of a dicrotic pulse in this series of patients.

Additional Indexing Words:
Arterial pulse  Aortic regurgitation

The "twice-beating" pulse is characterized by two palpable pulsations with each cardiac cycle and may be of the anacrotic, bisferiens, or dicrotic variety. The first two types are systolic in timing while the third is diastolic. The anacrotic pulse is usually associated with severe aortic stenosis and characterized by a notch on the up-stroke of the pulse tracing which is difficult to palpate. The bisferiens pulse is seen with hypertrophic subaortic stenosis or the combined lesions of mild to moderate aortic stenosis and aortic regurgitation. There is a notch at or near the summit of the pulse tracing which is easier to appreciate by palpation. Classically, the dicrotic pulse has been associated with typhoid fever, febrile illness, or mild to moderate aortic insufficiency; recently, it has been described with myocardial disease and failure. The dicrotic wave, which follows the dicrotic notch, is the most easily palpated of the three, and when marked, it is a striking clinical finding.

We have not found mention of the dicrotic pulse occurring after open heart operation, and therefore this experience is reported.

Methods

Clinical Material (Table 1)
A double radial pulse was first observed in case 4 (table 1) following valve replacement for aortic insufficiency on August 30, 1966. The double pulse disappeared with development of a leak around the prosthesis and returned when the dehiscence was repaired. The dehiscence recurred and the dicrotic pulse again disappeared only to return when the dehiscence was repaired at a third operation. (This case has been reported previously.) Arterial pressure tracings were obtained after the third operation.

We have since searched for a dicrotic pulse and have seen 17 additional patients in whom such pulses developed after operation (table 1).

Technic
Intra-arterial pressure tracings were obtained with indwelling arterial catheters (polyethylene, ID 0.575 mm, OD 0.95 mm, length 30 cm) placed in the brachial or common femoral artery using a P23Db Statham strain gauge and a Sanborn direct-writing amplifier recorder or a Sanborn photographic recorder. Radial, brachial,
Table 1

Summary of Data on 18 Cases Studied

<table>
<thead>
<tr>
<th>Case</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Dicrotic pulse Onset* (PO day)</th>
<th>Duration (days)</th>
<th>Lesion†</th>
<th>Orifice‡ (ID, mm)</th>
<th>Blood pressure (mm Hg)</th>
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<td>15.1</td>
<td>100/75</td>
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*0 = day of operation, 1 = first postoperative day, etc.
†AI = aortic insufficiency, AS = aortic stenosis, VSD = ventricular septal defect, TI = tricuspid insufficiency, MI = mitral insufficiency.
‡The orifice diameter of the appropriate Starr-Edwards prosthesis (aortic, series 1200; mitral, series 6120) as indicated.
§The dicrotic pulse disappeared on the first PO day and recurred on the 12th through 18th days.

carotid, femoral, or pedal pulses were detected percutaneously with a Sanborn APT-16 pulse wave transducer and inscribed with the same Sanborn photographic recorder. Tracings were obtained once or twice daily for 3 to 7 days and then at less frequent intervals at a paper speed of 25 mm/sec.

Results

In 14 of 18 patients the dicrotic pulse was associated with replacement of a regurgitant aortic valve (table 1). In the remaining four patients the lesions were a ventricular septal defect (case 3), recurrent ventricular septal defect and tricuspid insufficiency (case 5), mitral regurgitation (case 8), and congenital aortic stenosis (case 9). The dicrotic pulse usually appeared within 48 hours of operation and persisted 1 to 60 days. The blood pressure was within normal limits (table 1) when a dicrotic pulse was present and did not change in relation to appearance or disappearance of the dicrotic pulse.

Among the patients with aortic regurgitation the magnitude and duration of the dicrotic pulse were greater in the younger than in the older ones. The pulse was usually maximal a few days after its appearance, and then it gradually decreased. Although the dicrotic pulse was present only in the brachiocephalic vessels, the femoral pressure and pulse tracings and the pedal pulse tracings frequently contained an accentuated dicrotic wave.

The natural course of the pulse could not be followed in case 1 because the dicrotic pulse and wave disappeared coincident with the development of a leak around the prosthesis on the third postoperative day (fig. 1). In case 12 a dicrotic pulse was present on the first postoperative day, but it disappeared with development of a mechanical alternans and high serum enzymes indicating myocardial damage. A minimal dicrotic pulse returned from the 12th to the 18th postoperative day. In three older patients (cases 14, 15, and 17) the dicrotic pulse was minimal in that it...
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Radial pulse tracing (A) 24 hours after operation when there was a dicrotic pulse and (B) 72 hours after operation when aortic insufficiency had developed and the dicrotic pulse had abruptly disappeared (case 1).

Persisted only 24 to 48 hours and was present over the carotid arteries only. The oldest patient (case 18) died 6 hours after operation with myocardial failure and intermittently had a dicrotic pulse.

Inflation of a sphygomanometer cuff to 250 mm Hg immediately distal to a brachial artery cannula in case 4 did not alter the contour of the dicrotic wave. In the same patient intravenous injection of 1 mg of phenylephrine abolished the dicrotic pulse and altered the contour of the dicrotic wave significantly while raising mean arterial pressure 25 mm Hg (fig. 2). In case 18 a dicrotic pulse was present immediately after withdrawal of the extracorporeal support when systemic pressure was 100/70 mm Hg. Infusion of isoproterenol and norepinephrine raised the arterial pressure to 158/100 mm Hg, abolished the dicrotic pulse, and restored a normal dicrotic notch. The dicrotic pulse recurred after the infusion was discontinued and pressure had fallen.

As the dicrotic pulse diminished, the configuration of the dicrotic wave usually returned to normal over a period of days to weeks. This was true even in case 2 where the dicrotic pulse persisted for 2 months. However, in case 13 the dicrotic wave has remained prominent, and 1 year after operation the radial pulse is occasionally dicrotic. This patient had a large heart at the time of valve replacement, and it has not decreased in size indicating permanent myocardial damage and impaired function which is manifest by limited exercise tolerance.

All except one patient (case 18) survived operation. One late death (case 4) occurred.
wave, alteration of the pressure wave (increasing amplitude and appearance of a prominent diastolic wave) during transmission is a function of reflection from the periphery, particularly the arterioles.\textsuperscript{8-10} Transmission of the pressure wave without alteration in older persons is probably related to a decline in the reflection coefficient of peripheral arteries due to arterial degeneration.\textsuperscript{11}

Fourier analysis of the pressure wave during transmission in children having a "normal" dicrotic wave revealed that a change in contour of the pressure wave was always associated with alterations in amplitude and phase of the pressure wave harmonics. The degree of amplification was directly related to the amount of change in shape of the wave.\textsuperscript{11} Alterations of the pulse wave are even greater in the arm than in the leg.\textsuperscript{12}

Pharmacologic elevation of the blood pressure in two patients (cases 4 and 6) temporarily abolished the dicrotic pulse (fig. 2). Increased total peripheral resistance can lead to distention and loss of wall distensibility\textsuperscript{13, 14} with more rapid transmission and little or no alteration of the pulse wave. Conversely, decreasing the peripheral resistance can enhance the dicrotic wave.\textsuperscript{15}

A small stroke volume is a significant determinant of the dicrotic pulse.\textsuperscript{9} The dicrotic pulse was usually maximal a day or two after operation and then began to decline which is consistent with the gradual increase in cardiac output that occurs after aortic valve replacement.\textsuperscript{16} When stroke volume was increased for a single beat following a skipped beat, the associated dicrotic pulse was lost and the dicrotic wave became diminutive (fig. 3). The Valsalva maneuver results in diminished stroke volume, hypotension, and a dicrotic pulse.\textsuperscript{15} The duration of systole affects the amplitude and form of the pulse wave during transmission.\textsuperscript{15} This then implicates the contractile state of the myocardium.

The primary determinants of the dicrotic pulse are: the stroke volume, the duration of systole, the distensibility of the arterial system which correlates with age, and the systemic blood pressure which acts indirectly by

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**Discussion**

The determinants of the dicrotic wave and, therefore, of the dicrotic pulse are incompletely understood. Rebound of arterial blood against the closed aortic valve has been frequently offered as an explanation for the normal dicrotic wave. The normal dicrotic wave is diminished or lost with age, hypertension, arteriosclerosis, and diabetes mellitus.\textsuperscript{4, 5}

The dicrotic pulse is more pronounced in younger individuals and persists longer in them. The thoracic aorta is a distensible\textsuperscript{6} reservoir which may store half of the stroke volume during systole and eject it during diastole.\textsuperscript{7} Aortic wall stiffness increases with age and the reservoir function of the aorta is diminished.\textsuperscript{7} Although aortic wall stiffness influences the configuration of the pressure

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**Figure 3**

Radial pulse tracing while the heart was being paced at 130/min (case 11). The compensatory beat following a skipped beat has a normal dicrotic wave.

28 months later in another city, apparently related to progressive aortic insufficiency. A second late death at 33 months resulted from intrathoracic rupture of an ascending aortic aneurysm (case 15).
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modifying arterial distensibility and is a measure of vascular impedance and therefore of the peripheral reflection coefficient.

The fact that a dicrotic pulse was frequently recognized after correction of aortic regurgitation (34% incidence of dicrotic pulse versus a 3.5% incidence after all open heart operations) but only once after correction of aortic stenosis (0.5% incidence) suggests that there may be something specific about the former that disposes to a dicrotic pulse. Blood pressure and heart rate were not different in the two groups. Cardiac output and stroke volume were not measured but did not vary significantly in a small group of patients studied. It is possible that there is some accommodation of the arterial system to aortic regurgitation so that its reservoir function (distensibility) is enhanced. With abrupt correction of the regurgitation a prominent diastolic wave results. On the other hand, myocardial failure and low output may be more prevalent in aortic regurgitation than in aortic stenosis.

References

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