skin, or division of peripheral nerves, as in Stoeffel's operation, are not popular with most surgeons. The results are unsatisfactory. The technique of Ball's operation is difficult to carry out, although appearing easy on paper, and the rationale of dividing definite nerve lesions being sound.

Lockhart-Mummery, however, states he has performed this operation since 1905 with excellent results, and advises it in old standing cases.

Deep X-ray therapy is not recommended owing to various risks involved in skin changes and frequency of relapse.

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SURGICAL CLOSURE OF THE PATENT DUCTUS ARTERIOSUS

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Interest in persistent patency of the ductus arteriosus has increased greatly since surgical ligation of this vessel was first successfully performed by Gross in August 1938 (Gross and Hubbard, 1939). Munro (1907) suggested such an operation in infants, but it was not till Strieder (Grabiel, Strieder and Boyer, 1938) attempted its performance in an adult that the practical possibilities of this procedure received serious consideration. Further interest has been stimulated by the demonstration that some cases complicated by subacute bacterial endarteritis can be cured of their infection by ligation (Touroff and Vessell, 1940, and Bourne, Keele and Tubbs, 1941).

Up to the present time about 200 cases of patent ductus arteriosus have been treated surgically, and it is therefore time for a careful review of the results obtained and the indications for and technique of the operation. Nine of my own 12 cases have been ligated in the presence of endarteritis, and the importance and frequency of this complication will receive particular attention.

Pathological Effects of Persistent Patency of the Ductus Arteriosus

During foetal life the ductus arteriosus is a relatively large vessel connecting the bifurcation of the pulmonary artery to the aorta, and has the important function of allowing a large part of the right ventricular output to enter the aorta without passing through the pulmonary circulation (Fig. 1). Normally the vessel becomes functionally closed within a few minutes of birth (Barclay et alia, 1942), almost certainly as a result of contraction of

![Fig. 1.—Diagrammatic representation of the foetal circulation (arrow in the ductus showing the direction of blood flow).](image-url)
and there is therefore no cyanosis unless the picture is complicated by severe heart failure. The amount of blood lost from the systemic circulation into the pulmonary circuit has been investigated by Eppinger and Burwell (1940): under the conditions of operation for ligating the ductus, these authors state that 45-75% of the left ventricular output subsequently passes through this vessel into the pulmonary artery, but this figure seems almost unbelievably high. The effect on the systemic circulation may be compared to that of aortic regurgitation for, although the systolic pressure is maintained or even raised, the diastolic pressure is lowered as a result of the blood lost from the aorta: obviously the blood lost in this way varies directly with the calibre of the ductus, and the diastolic pressure may therefore be taken as an index of its calibre. In order to maintain an adequate peripheral circulation the left ventricle frequently hypertrophies. The right ventricle likewise has increased work and may hypertrophy as it has to maintain its output against a raised pulmonary pressure which also causes dilatation and often atheroma of the pulmonary artery and its branches.

If the ductus remains patent as a compensatory mechanism to some other abnormality, e.g. pulmonary or aortic stenosis, peripheral cyanosis will be present. This needs stressing as the opposition to surgical treatment has largely been based on the grounds that the ductus remains patent as a safety channel to compensate for some other congenital cardiac defect: although this is often true (62% of cases of patent ductus arteriosus described by Maude Abbot (1936) had some other cardiac abnormality) such cases are clinically cyanosed and are therefore readily distinguished from the simple case for which operation is contemplated.

In addition to causing the circulatory disturbance and consequent compensatory changes described above, a patent ductus may become the site of subacute bacterial infection. The frequency with which this complication occurs is extremely difficult to assess. Bullock, Jones and Dolley (1939) collected 80 cases of simple patent ductus over the age of 3 which had been subjected to autopsy, and they found that 53% of these patients had died of subacute bacterial endarteritis, but autopsy statistics are not reliable evidence of the true incidence of this complication. To obtain an accurate figure, a large series of cases would have to be followed over a period of many years, an investigation which would be exceedingly difficult, if not impossible, to conduct. Wilson and Lubschez (1942) followed a series of 38 patients aged 10-19 for an average period of 6.8 years and 30 patients aged 20-29 for an average of 5 years (bacterial endarteritis has its maximum incidence between the ages of 16 and 25) and no case became infected. Shapiro and Keys (1941) also observed a series of 23 patients (average age 20) over a period of years without the occurrence of endarteritis, but the period of observation in both these series is too short to have much significance.

When infection does occur the vegetations appear first at the pulmonary end of the ductus or in the adjacent part of the pulmonary artery: consequently, any embolism which takes place at this stage is always into the pulmonary circulation. The inflammatory change may not be confined to the intima but involve the entire vessel wall rendering it friable and occasionally causing aneurysmal dilatation—pathological changes which
are of great importance to the surgeon undertaking the operation of ductal closure in the presence of endarteritis.

Later the vegetations may extend into the aortic end of the ductus or back along the pulmonary artery to the pulmonary valve: the other heart valves may also become involved. When the aortic end of the ductus or the valves of the left side of the heart become affected, embolism may of course occur into the peripheral circulation.

The Diagnosis of Patent Ductus Arteriosus and its Complications

The diagnosis of an uncomplicated patent ductus can be made with great accuracy and is usually easy. Shapiro and Keys (1943) in an analysis of 140 recorded cases submitted to operation found that errors in diagnosis had been made in only 2 cases.

The symptoms are relatively unimportant in making the diagnosis, but are significant when considering the indications for ligation: they may be divided into the following groups:

1. No symptoms at all. Absence of symptoms is commonly met with during the first two decades of life although the patient may be aware that the heart is congenitally abnormal as a result of some routine medical examination, e.g. that at school.

2. Failure to develop normally. It is said that a patent ductus is characteristically associated with a thin pale individual whose stature lags behind the average, and that this is due to the diminished peripheral circulation. It seems that this failure to develop normally may have been over-stressed as only 4 of my 12 cases submitted to operation could be considered other than of normal physique. Shapiro and Keys (1943) also comment that, with one exception, all their 23 patients were well developed.

3. A disagreeable sensation of throbbing. In addition to palpitation, the patient may complain of an abnormal perception of peripheral pulsation, especially after exercise, as a result of the high pulse pressure. Occasionally the cardiac murmur is audible to the patient, particularly when lying down, and is the source of vexation.

4. Symptoms of cardiac failure. Cardiac decompensation may occur at any age but is uncommon before the third decade: the preceding period of 20–30 years of healthy vigorous and often symptom-free life probably accounts for the prognosis of subjects with a patent ductus having been viewed with such optimism. When failure does set in, dyspnoea and even orthopnoea may precede the other symptoms of congestive failure by several years; this is accounted for by the increased blood volume in the pulmonary circulation which causes diminution in the vital capacity.

5. Symptoms of complicating endarteritis. The initial symptoms of bacterial infection of the ductus are usually those of any general infection, i.e. fever, malaise, sweating, loss of weight and sometimes minor rigors. As with other forms of subacute bacterial endocarditis, dental extraction with its not infrequent sequela of bacteraemia may be the source of the infection (the endarteritis in 2 of my 9 infected cases followed closely on removal of teeth). The symptoms of a generalised infection are sooner or later followed by those of pulmonary infarction, i.e. pleuritic pain and cough with exacerbation of the fever. Symptoms of systemic embolism (pain of sudden onset due to embolism in any part of the body, haematuria, etc.) may occur in the later stages.

The physical signs of an uncomplicated patent ductus are so distinctive that the diagnosis can be made with the greatest confidence. Essentially these consist of a continuous "machinery-like" murmur with its maximum intensity at the end of systole or early in diastole, and best heard in the second left intercostal space: the murmur is usually of such intensity that a thrill with the same timing as the murmur can be felt in the same space. If this characteristic murmur is not found, the diagnosis is almost certainly not that of uncomplicated patent ductus although the diastolic fraction is said to be sometimes absent in infants.

The absence of cyanosis has already been emphasised; if the patient is cyanosed the diagnosis is open to grave doubt unless marked heart failure is already present. The lowering of the diastolic blood pressure has been referred to previously; 50–60 mm. Hg. is an average figure, but readings lower than this may be recorded when the ductus is very large: the systolic pressure is normal or slightly raised so that the pulse pressure is high which may be recognised clinically by the presence of a Corrigan pulse, capillary pulsation and exaggerated arterial pulsation in the neck.

A teleradiograph may show enlargement of the heart shadow especially on the left side and congestion of the pulmonary vessels but the distinctive feature is the alteration in the cardiac contour due to the dilated pulmonary artery which forms a "bulge" below the aortic "knuckle." If the patient is screened, exaggerated pulsation in the pulmonary arterial "bulge" and increased ventri-
cicular movement can be seen: these augmented movements can be recorded by kymography.

The electrocardiogram is essentially normal although there may be slight axis deviation.

The first signs of cardiac decompensation are progressive cardiac enlargement and rales at the bases of the lungs indicating pulmonary congestion. Cyanosis may also be noticed but signs of congestive failure appear relatively late.

When bacterial infection occurs, no additional signs other than fever may be found. As the diagnosis of superimposed infection must be made at the earliest possible moment in order to ensure a satisfactory result from surgical ligation, any case of patent ductus which runs an unexplained fever for more than 2 weeks should be strongly suspected of having developed this complication and steps taken to confirm the diagnosis. Such confirmation can usually be obtained by culture of the blood taken just before the fever reaches its daily maximum, but it is essential that this investigation should be performed by an expert pathologist if reliable results are desired; in his hands repeated sterile cultures are most unlikely if bacterial endarteritis is present. Streptococcus viridans is the infecting organism in the vast majority of cases, so that infarcts due to separation of fragments of the vegetations rarely undergo suppuration. It has been already pointed out that infarction occurs first in the pulmonary circuit: these infarcts can usually be seen in radiographs of the chest although physical signs other than transient pleural friction are often absent. If the vegetations have spread to involve the aortic end of the ductus or the mitral or aortic valves, evidence of systemic embolism (petechiae, Osler nodes, haematuria, etc. etc.) may be found.

When the endarteritis has been present for some weeks secondary anaemia and splenic enlargement (independent of splenic embolism) make their appearance.

Indications for Operation

As those who have been concerned with the operation of surgical closure of the ductus arteriosus are not yet in complete agreement with regard to the indications for operation, it is necessary to consider these at some length.

1. Bacterial Infection. The presence of bacterial infection is unquestionably the strongest indication for operation as at least 60% can be cured by ligation. Shapiro and Keys (1943) collected 33 infected cases from the literature and found that 20 were cured: this is similar to my series of 9 patients with 6 alive and well to-day (the interval since the last successful operation is 22 months). A successful result in a case of this type is indeed dramatic, for the sulphonamides and even penicillin appear to have made little change in the almost uniformly fatal prognosis.

A slight point of controversy arises in this group, for it has been found that operation rarely cures the patient if the vegetations have spread to the aortic end of the ductus or to the mitral or aortic valves: consequently, some surgeons (Touroff, 1942) maintain that evidence of such extension, i.e. the finding of systematic embolism, is a contra-indication to operation, but personally I feel that even these patients should be operated upon until we have further evidence indicating that such treatment is futile beyond question, because my first case ultimately recovered in spite of petechiae and haematuria being present before operation. (This case proved in fact to be the first successful result ever obtained by ligation in the presence of infection.)

2. Cardiac decompensation. It is generally agreed that any evidence intimating decompensation for the circulatory defect is an indication for surgical closure of the ductus. This indication may be developed further if those patients who are likely to become decompensated later in life are included under this heading. Can such a forecast be made, with any degree of accuracy? The answer to this question cannot be given with any dogmatism, but it is probable that those patients with a ductus of large calibre or with enlargement of the heart are more likely to become decompensated than those with a normal-sized heart and a narrow ductus: enlargement or obvious overactivity of the heart and a low diastolic pressure (under 60) may therefore be considered indications for surgery in order to prevent rather than treat heart failure.

Incidentally, those patients who complain of a disagreeable sensation of throbbing usually have a low diastolic blood pressure, so that the indication for closure of the ductus will come into this group.

3. Failure to develop normally during childhood and adolescence. If a child with a patent ductus is underweight in spite of adequate nourishment, operation is almost certainly to be recommended as there is good evidence that normal development will then take place. It is sometimes difficult to decide whether growth is lagging behind the normal for the individual concerned, but comparison with other siblings will often settle the point.
A much easier way of facing the problem of selection of cases for surgery is to maintain that every case in which patency of the ductus is diagnosed as the sole congenital cardiac abnormality should be treated by operation, preferably at about the age of 7. The supporters of this view claim that operation is then undertaken before any secondary damage has occurred to the cardiovascular system and before the likelihood of bacterial endarteritis. (It has yet to be proved that a surgically-closed ductus is entirely free from the risk of superimposed infection, although it is reasonable to suppose that this is likely to be the case if closure is complete.) In addition, secondary dilatation of the pulmonary artery which increases the technical difficulties of operation is minimal and children are said to be less disturbed by the operation than adults. Finally there is evidence that progressive shortening of the ductus may occur with age, so that the "window type," in which there is no real channel but a mere stoma between the aorta and pulmonary artery and which may make ligation exceedingly difficult or impossible, is rarely met with. (Although the ductus has been very short in several of my patients, the only case in which I have had to abandon the attempt at closure because of the presence of a stoma rather than a channel was in a girl of 9.) These arguments make a very plausible case, especially when the operative mortality is shown to be exceedingly low in competent hands, and this view may well prove the correct one, but I believe that at present we should limit our recommendations for operation to those people having the indications already discussed and follow carefully the course of those without symptoms and having a normal-sized heart and a diastolic pressure of 60 or above.

Surgical Technique

No special preparation for operation is required except it is an advantage to render the infected cases afebrile when this is possible by means of chemotherapy. Streptococcus viridans varies in its sensitivity to the sulphonamides, but many patients with this infection respond temporarily to their administration and become afebrile so that the general condition improves. Although some exceedingly ill patients are very little disturbed by closure of the ductus, the improvement sometimes obtainable with the sulphonamides may be valuable, and I am therefore in favour of giving one of them for 4 or 5 days prior to the planned date of operation. It would probably be even better to use penicillin for this purpose. I agree wholeheartedly with those who warn against the prolonged use of chemotherapy in an attempt to cure the patient, for such treatment is almost certainly doomed to ultimate failure and the patient's general condition will then have deteriorated before operation. Another criticism against using chemotherapy at all has been that the effect of the operation per se is confused by the use of these drugs: this is certainly true, but there is now ample evidence that it is the operation and not the chemotherapy which makes the blood permanently sterile.

The use of intravenous fluids during the operation is debatable as the blood volume may be already increased to compensate for patency of the ductus, but it is a sound precaution to set up a very slow "drip" before starting, so that one is fully prepared for the remote chance of severe accidental haemorrhage.

Cyclopropane given through an ordinary face-piece is probably the best anaesthetic as it allows such perfect oxygenation of the blood with minimal respiratory movement of the operative field.*

Exposure of the subaortic region is obtained through the anterior chest wall by most surgeons. I have always used an incision placed directly over the second left intercostal space with a small additional vertical mid-line cut so as to facilitate exposure of the second and third costal cartilages (Fig. 3): after removal of an inch of each of these cartilages the pleural cavity is widely opened through the exposed space (Fig. 4)† and adequate access to the desired part of the mediastinum is obtained.

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* Since writing this paper two patients have developed a pulse rate of over 200 following the administration of cyclopropane and before starting the operation for closure of the ductus. Ether and oxygen using a closed circuit proved very satisfactory in a later case and will be employed in further cases as ether does not cause cardiac irregularities so commonly experienced with cyclopropane.

† See art page insertion.
obtained by the use of a "rib-spreader." This method allows room for the subsequent manoeuvres but not in abundance, so that, in case of difficulty or accident, the surgeon might be rather cramped.

Gross (1944), in order to obtain a better cosmetic result, uses a submammary skin incision with subsequent retraction of the breast upwards and laterally, and enters the chest through the third intercostal space combining this with division of the second and third costal cartilages. Harrington (1943) has recommended a *postero-lateral* incision through the fourth space, and states that this exposure provides ample room to deal with any difficulties that may be encountered in isolating the ductus: there is no doubt that postero-lateral incisions in the chest in general give wider access to the mediastinum than those placed anteriorly, but on the other hand, they cause more disturbance to the cardiovascular system and more pain.

In order to expose the ductus, the mediastinal pleura is picked up in a clamp just behind the phrenic nerve and below the aortic arch and incised vertically (Fig. 5): the pleura is then gently separated from the aortic arch and from the neighbouring part of the pulmonary artery and its left branch.

The anatomy of the region is thus fully exposed: the over-distended pulmonary artery in which a thrill is readily palpable will have been recognised previously, but it is now possible to identify the vagus with its left recurrent laryngeal branch looping under the aortic arch postero-lateral to the aortic attachment of the ductus, and the superior intercostal vein will also be seen as it crosses the upper part of the aortic arch transversely. A finger-like process of serous pericardium is not infrequently found overlapping the infero-medial part of the anterior surface of the ductus: in such cases I have intentionally opened this part of the pericardial sac (on 3 occasions), but I feel sure that it would be preferable to strip this process unopened towards the heart as recommended by Gross (1944), because the leak of pericardial fluid obscures the field and post-operative pain with pericardial friction sometimes follows. If any doubt remains at this stage as to the identity of the ductus, confirmation can be obtained by palpation as the maximum thrill is felt over it: in addition, compression of the ductus by backward digital pressure will diminish or abolish the thrill.

The next step is isolation of the ductus from the surrounding tissues. In infected cases this should be started at the aortic end, as the endarteritis, which is liable to make the wall friable, is usually less marked in this part and there is therefore less likelihood of perforation of the vessel. The isolation is carried out by blunt dissection, the tissues being separated carefully with a long, curved haemostatic forceps (Fig. 6) and by the use of a pledge of gauze held in a clamp. Freeing of the postero-medial wall, which cannot be seen, is the most difficult part of the operation, but may be completed by the cautious use of a very blunted aneurysm needle. The length of the ductus is variable but, in my experience, has been never more than 1.5 cm. and usually much shorter: the working space between the pulmonary artery and aorta varies directly with the length of the ductus, and in those uncommon cases where the ductus is but a stoma between the two main vessels, isolation may be impossible. My twelfth case (aged 9 and uninfected) proved to have such a ductus and isolation was not completed as an attempt to open up the space behind the stoma resulted in considerable venous bleeding—probably from a small tear in the posterior wall of the pulmonary artery near the attachment of the ductus: fortunately the bleeding ceased spontaneously but it seemed wise to abandon further attempts to isolate the channel, and the patient, who subsequently recovered satisfactorily, was returned to the ward without the purpose of the operation having been fulfilled. While freeing the ductus from the surrounding tissues the recurrent laryngeal nerve may become sufficiently contused to interfere with conduction, and temporary hoarseness of the voice is occasionally heard after operation.

The means whereby permanent closure of the ductus may be invariably obtained is still being studied. It is common knowledge that ligation of a large artery in continuity is no guarantee that obliteration of the lumen will be permanent, and experience has shown that the ductus is no exception to this observation. A diastolic murmur heard in the pulmonary area after operation is almost certain evidence of persistance or recurrence of the leak from the aorta into the pulmonary artery, and this has been found in 3 of my 10 completed cases which survived operation. Other surgeons have had a similar experience. It is obvious that a thick soft ligature tied sufficiently tightly to obliterate the lumen of the vessel without damaging its wall is less likely to cause pressure necrosis, and thus recanalisation, than fine harsh material tied as tightly as possible. For this reason I have used doubled No. 5 tubular silk, except in the last case in which floss silk was employed; the floss silk did not cut into the vessel at all and appeared a great improvement on the other. Gross (1944), having tried with incomplete success various manoeuvres including injection of sclerosing solution between the ligatures and wrapping cellophane round the ligated ductus in order to produce

* See art page insertion.

* See art page insertion.
progressive fibrosis, has reported 14 consecutive successful cases (including 2 with infection) in which the ductus has been divided between clamps and the ends sutured. This is clearly the ideal and a remarkable achievement, especially in view of the same author's previously expressed opinion that the ductus has always appeared too short to divide safely between ligatures.

As soon as the lumen of the ductus is occluded the diastolic pressure rises to a normal figure or, sometimes, to a figure in excess of the expected normal: the systolic pressure occasionally rises as well, although proportionately less. In a few cases the effect of these pressure changes has been to diminish the pulse pressure to less than 40 so that the pulse volume feels poor, but both systolic and diastolic pressures usually adjust themselves to the expected normal within the first few days. Closure of the ductus also causes immediate abolition of the thrill and, if a sterile stethoscope is placed on the pulmonary artery, no murmur other than perhaps a faint one in systole will be heard. Generally the effect on the heart beat appears negligible except that extra systoles (Fig. 7) occasionally occur during the first few minutes: however, in one of my infected cases which suffered in addition from advanced heart failure with orthopnoea and gross enlargement of the heart, the cardiac contractions immediately weakened resulting in rapid fall of the systolic pressure and the patient died 2½ hour after completing the operation.

The mediastinal pleura is left unsutured so that any exudation of blood or serum may escape into the pleural cavity from which it can be aspirated.

The chest is then closed in layers and finally the air is withdrawn from the pleural cavity by means of a pneumothorax apparatus. If an anterior incision has been used it is important to suture both deep and superficial fasciae in order to avoid the scar stretching and becoming unsightly.

Post-operative Course and Treatment

The post-operative course is usually smooth and special treatment is rarely required. The patient is returned to the ward lying flat and kept in this position for at least the first few hours; subsequently the semi-sitting position is the most satisfactory. Morphine should be used to control restlessness and oxygen given if there is any suggestion of cyanosis, but this is exceptional.

In none of my cases has there been sufficient collection of pleural fluid to require aspiration, but the possibility of this being needed should be borne in mind. The uninfected case should be fit to get out of bed in about 10 days.

The infected cases make an extremely interesting group for investigation, as the reason for their recovery remains unknown. Touroff (1942) has compounded a theory which supposes that, following closure of the ductus, the vegetations cease to be fragmented by the swirl of blood coming through the ductus and that the few fragments which do become dislodged are filtered off by the

![Fig. 7.—Electrocardiograph tracings (lead 2) taken during operation of ligation of the ductus. Upper tracing taken just prior to ligations, the middle one (showing extra systoles) taken immediately after ligations, and the lower 15 mins. later.](http://pmj.bmj.com/content/21/235/158)
May, 1945

PULMONARY CAPILLARIES WHICH ARE NO LONGER DILATED BY A RAISED PULMONARY PRESSURE. THIS IS HYPOTHETICAL BUT REASONABLE AS IT ACCOUNTS FOR THE

amazingly rapid reduction in the number of bacteria circulating in the blood (Fig. 8).

The pyrexia in an infected case is immediately reduced by operation and usually ceases altogether within the first 10 days (Fig. 9). Sometimes one or more sudden rises of temperature occur during the first 7–10 days; such fever is usually associated with pleuritic pain and is almost certainly caused by a portion of the vegetations being carried into the lung as an embolus.

I have already stated that 6 of my 9 infected cases have made a complete recovery and are alive and well to-day although two of them have evidence of a leak through the ductus, but it may be instructive to review the three failures. In the first, recanalisation of the ductus occurred one month after operation and death due to the original infection followed 4 weeks later. In the second, death resulted from acute heart failure 3 hours after completing the operation. (Both these cases have been mentioned previously.) The third death was due to subacute endocarditis of the mitral and aortic valves although there had been no evidence of this before operation, and the ductus was found to be completely closed and free of infection at autopsy. Looking back on these it seems possible that the first fatality might have been avoided by better technique, although the thrombus was found almost to occlude the pulmonary artery at autopsy (Tubbs, 1944). The second case should have been operated upon much earlier as there were no symptoms or signs of heart failure when the diagnosis of endarteritis was first made 3 months previously. Failure in the third patient was probably unavoidable as she was operated on within a month of the onset of infection.

I have only operated on 3 uninfected cases. Two were adults in whom symptoms and signs of early heart failure had appeared; both are well to-day with apparently completely normal hearts, and both are most emphatic on their increased ability to exert themselves. The last case was a child of 9 with an enlarged over-active heart and lacking the robust health of her two brothers; failure to ligate the ductus in this case due to its brevity has already been described.

### Illustrative Case Reports

1. **Case with Subacute Bacterial Endarteritis**

A girl of 17 had known from childhood that she had a so-called "weak heart," but she had noticed no disability and had been perfectly well until some teeth were extracted 10 weeks before admission on October 22, 1941. Following this operation she felt weak and feverish, and later developed left-sided pleuritic pain. On examination she looked pale and ill: there was a daily rise of temperature to 101° F. and...
the pulse rate averaged 120. The heart was not enlarged but the classic signs of a patent ductus arteriosus were present and the blood-pressure measured 116/58. No evidence of embolism could be found, but 143 colonies of streptococcus viridans per c.c. of blood were obtained on shake culture. Sulphapyridine was given by mouth; as a result the fever entirely subsided for a week and the blood became sterile, but pyrexia and bacteriaemia then returned and persisted in spite of various sulphonamides. (This case is a good example of the importance of planning the operation to take place within a week of starting chemotherapy.) The ductus was ligated on December 4, 1941, although the patient was very ill at the time. At operation areas of infarction were seen in the left lung. Difficulty was experienced in isolating the posterior surface of the ductus as the tissues were very adherent and a small tear was made into it, but the bleeding was easily controlled with a clamp. The vessel was then ligated above and below the tear. The diastolic pressure immediately rose from 58 to 76 and the thrill and "machinery" murmur were abolished. The patient became afebrile at once and blood taken two days after operation was sterile (Fig. 9). Apart from sudden left-sided pleuritic pain on the seventh day with a rise of temperature to 102°F., presumably due to a pulmonary embolus, convalescence was smooth and no further positive blood cultures were obtained.

This girl remains perfectly well to-day, 3 years after operation, with no abnormal cardiac signs except a short, faint systolic murmur.

2. Uninfected Case with Early Heart Failure

A printer's compositor of 29 was admitted on May 18, 1944, complaining of breathlessness and fatigue after minor exertion. Although he had been active as a child he used to feel unduly tired after exertion even at this stage of his life and did not play games at school. Breathlessness had been noticed latterly and was now considerable after climbing one flight of stairs. Each day's work left him completely exhausted. On examination he was well developed and not breathless while in bed. The pulse was of Corrigan type and the blood pressure measured 148/50. The heart was moderately enlarged (apex beat 1 inch outside the nipple line) and showed the classical signs of a patent ductus. There was no objective evidence of cardiac insufficiency. The ductus was ligated with floss silk on May 22, 1944. One hour after operation the blood pressure measured 110/90 and the pulse was of poor volume, but 6 hours later the pulse pressure had risen to 40 (140/100). The patient left hospital on June 14th in good condition with a blood pressure of 128/70. He was seen last on January 6, 1945, when he stated that he no longer suffered abnormal fatigue or breathlessness and expressed extraordinary gratitude for the operation. The heart showed no abnormal signs and the blood pressure measured 124/80.

3. Case in which the Indications for Operation were considered to be Absent

A girl of 14 was referred for investigation of a "murmur in the heart" by the doctor of a company to which she had applied for employment. The murmur had been discovered on routine school medical examination at the age of 5, but she had been told not to worry about it and had since led a very active life playing netball, doing physical training and dancing without any discomfort. On examination she appeared a healthy, robust girl (weight 7 st. 2 lbs.) and had no cyanosis. The classic signs of a patent ductus were present although the diastolic element of the murmur was less prolonged than usual. There was little, if any, cardiac enlargement and the blood-pressure measured 110/62. These signs were accepted as evidence of a narrow ductus for which operation was not justified, and the patient was discharged with instructions to report to hospital at once if she ever suffered from unexplained fever.

Summary

1. Surgical closure of the ductus arteriosus has stimulated great interest in this congenital abnormality.
2. The altered circulation due to the ductus is discussed and the absence of cyanosis in cases where it is the only lesion emphasised. The pathology of bacterial endarteritis as a complication is described.
3. The indications for operation are critically analysed. The author is of the opinion that the time has not yet arrived when operation should be urged for all cases: complicating bacterial infection should be diagnosed early, and the patient promptly treated by closure of the ductus: heart failure or cases likely to develop this, and retarded growth during childhood are also indications for surgery.
4. The technique of the operation and the difficulties and complications which may arise are described. Permanent closure of the
ILLUSTRATIONS ON SURGICAL CLOSURE OF THE PATENT DUCTUS

By

O. S. TUBBS, F.R.C.S.

Fig. 4.—The second intercostal space exposed. (View from the left side of the patient as by the surgeon.)
(Reproduced by kind permission of the British Journal of Surgery.)

Fig. 5.—Pleural cavity opened and lung depressed under a lighted retractor. The mediastinal pleura has been picked up below the aortic arch and behind the phrenic nerve.
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Fig. 6.—Stages in isolation and ligation of the ductus. The proximity of the recurrent laryngeal nerve after leaving the vagus is shown.
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Fig. 1.—Fracture-dislocation of neck of humerus with rotation of head of humerus.

Fig. 2.—Contusion fracture of head of humerus.

Fig. 4.—Fracture of lower one-third of shaft of humerus, showing onlay graft with vitallium screws.

Fig. 5.—Supra-condylar fracture of humerus, with backward displacement.
Fig. 6.—Supra-condylar fracture of humerus, with anterior displacement.

Fig. 7.—Fracture-dislocation of capitellum plus half of Traclea.

Fig. 8.—(above) Fracture-dislocation of external condyle of humerus, with rotation of the fragment.

Fig. 9.—(above) Fracture-dislocation of internal epicondyle of humerus, with displacement into the joint.

Fig. 11.—Anterior dislocation of elbow joint.
Fig. 10.—Lateral dislocation of elbow joint.

Fig. 12.—Fracture-dislocation of elbow joint, first described by the writer, showing a Monteggia type, with a longitudinal fracture of the ulnar shaft.

Fig. 14.—"Irreducible" fracture of shaft of radius due to interposition of pronator quadratus. Open reduction is essential.

Fig. 15.—Colles fracture-dislocation. Lateral view shows dorsal displacement and dorsal rotation of distal fragment.

Fig. 13.—Monteggia fracture-dislocation of the shaft of the ulna and head of the radius, with secondary "myositis,"
duct in all patients treated by ligation has not yet been achieved, and division between clamps may supersede simple ligation.

5. The effects and results of operation are reviewed.

6. Illustrative cases are recorded.

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FRACTURES II

THE UPPER LIMB—DIAGNOSIS AND TREATMENT

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It is rarely emphasised in writing that the treatment of fractures generally is very difficult. Nowhere does this apply more than to the common fractures occurring in the upper limb. For example, it is extremely difficult to obtain absolute anatomical and functional correction in many fractures of the elbow and the wrist in adults. Writers only too frequently suggest that such fractures can be easily reduced and full correction obtained. Such statements only depress the reader, who may be having considerable difficulties in his treatment of these fractures. It is only fair to indicate which fractures are difficult to treat and to indicate methods by which the treatment of these difficulties can be rendered more effective.

Nevertheless, the general standard of results still obtained from such fractures as those of the elbow, forearm, and wrist in adults is far too low. This standard can be raised by greater care in treatment, more attention to detail, a desire to obtain better anatomical and functional results than heretofore, and better after-treatment to the soft tissues and to the joints not immobilised.

Radiographic Diagnosis

More and more the finer points of the diagnosis of fractures rest upon the methods of radiographic procedures. It is still true that clinical examination is pre-eminent, but only too frequently the only clinical sign is tenderness at the site of the fracture.

In injuries to the limbs the whole of a long bone should be X-rayed. Also the joints above or below the fracture must be included in the film. X-rays of both limbs should be taken for comparison. Especially is this necessary in the case of joint injuries. Furthermore, X-rays must be taken in at least two planes at right angles, and preferably in a third oblique plane.

Fractures of the Clavicle

Fractures of the clavicle occur most commonly in the middle and towards the outer extremity. The chief points concerning treatment are the avoidance of stiff fingers and a stiff shoulder. The usual method of treatment by three handkerchiefs or figure of eight bandage is very painful if applied properly, or ineffective if applied comfortably. The reader has only to permit himself to be tied tightly for one night with three handkerchiefs to appreciate this point.

The most efficient and most comfortable method is to place a four-inch square of adhesive felt on the fracture site and a similar square of adhesive felt on the under-surface of the olecranon. Elastoplast is then applied from the axilla on the inner side of the arm, round the under surface of the elbow, up the outer aspect of the arm, around the clavicular felt pad, and across the trapezius to the back. Two pieces of elastoplast are so fixed with one circular piece loosely around the arm. This enables the patient to move the shoulder, elbow, and hand from the beginning.

Sayre's method is absolutely contra-indicated as it prevents active movements of all the joints.

Fractures of the Scapula

The scapula may be fractured in the body, neck, coracoid process, or acromion. Although frequently badly splintered by multiple fissure fractures the correct treatment for all these fractures is radiant heat and active exercises from the first day of injury.

Passive exercises should never be given in injuries of the limbs, in fact the writer is convinced that it has no place in bone and joint surgery. The only indication for passive exercises is paralysis associated with a nerve lesion.