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Aortic cannulation

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Some problems of cannulation of the ascending aorta are demonstrated. Improved perfusion of the aortic arch is subsequently shown with a metal cannula having a basket-shaped tip. The design of the tip breaks the perfusing jet into four weaker jets, thus preventing differential perfusion of an arch vessel.

In heart–lung bypass the arterial blood can be returned to the patient by a variety of methods; these differ in the type of cannula used, the site of insertion, and the technique of insertion. 'Cannulae' have been fashioned from both biological (homograft aorta; Dodrill, Marshall, Nyboer, Hughes, Derbyshire, and Stearns, 1957) and synthetic materials (metal and plastic ; Nuñez and Bailey, 1959). The infusion sites commonly used are the femoral artery and the ascending arch of the aorta, with a growing preference in recent years for the latter site.

There is little in the literature about the complications of aortic cannulation, compared with that found in ilio-femoral cannulation (Jones, Vetto, Winterscheid, Dillard, and Merendino, 1960 ; Elliott and Roe, 1965). However, death from cerebral haemorrhage, attributable to imperfect aortic arch perfusion, has been reported (Kulkarni, 1968), and, in a recent paper on aortic cannulation, some disadvantages of the site are briefly mentioned by Borman and Milwidsky (1968). To these must be added the post-perfusion death, where imperfect perfusion of the aortic arch is suspected, especially when this is associated with the small aortic arch of a child. Unfortunately, imperfect perfusion of the head will not normally be evident during bypass, may only be suspected when the patient fails to regain consciousness, and will often be undetectable even at post-mortem examination. It is prudent to point out that, during heart–lung bypass, a low radial artery pressure, associated with a very high line pressure unrelated to the resistance in the actual line, implies inadequate aortic arch perfusion.

Concern about the possible dangers of aortic arch cannulation, as currently practised, and experimental evidence of the better haemodynamics of perfusion via the femoral artery, prompted this study of the factors involved, and led to the development of an improved method of aortic cannulation.

METHOD

Animal (14–30 kg.) bypass experiments were performed, in addition to perfusion studies using a simulated aortic arch and great vessels. The perfusion techniques duplicated those used at clinical operations for a valid comparison of results. The perfusion line was 10 mm. internal diameter (I.D.) tubing for all experiments, and perfusion flows were in the clinical range. Pressures from the left and right axillary arteries and the femoral arteries were recorded. The infusing sites were the femoral artery and the ascending aotic arch. Initially, arterial pressures were monitored when perfusing with the standard femoral metal cannulae at either site. Further recordings were then made whilst perfusing with the large (6 mm. I.D.) and small (4 mm. I.D.) Simplastic perfusion catheters[1] in the ascending aorta.

Finally, in an effort to resolve some of the problems encountered, a new design of cannula (Figs 1a, b) was evolved to perfuse the aortic arch.

With all experiments the perfusing jet was manœuvred in order to show any pressure changes that might arise by differential perfusion of the aortic arch arteries.

RESULTS

SIMPLASTIC CATHETER With this method of perfusion in the smaller aorta, there was a difference in pressure between the left and right axillary arteries. With the small catheter, as used for a child with a small aorta, Fig. 2a was recorded when the catheter was inserted less than the described distance of 7–10 cm. (Matar and Ross, 1967). With this catheter further introduced to a distance of 25 cm., Fig. 2b was recorded.

[1]Simplastic catheters, J. G. Franklin, London

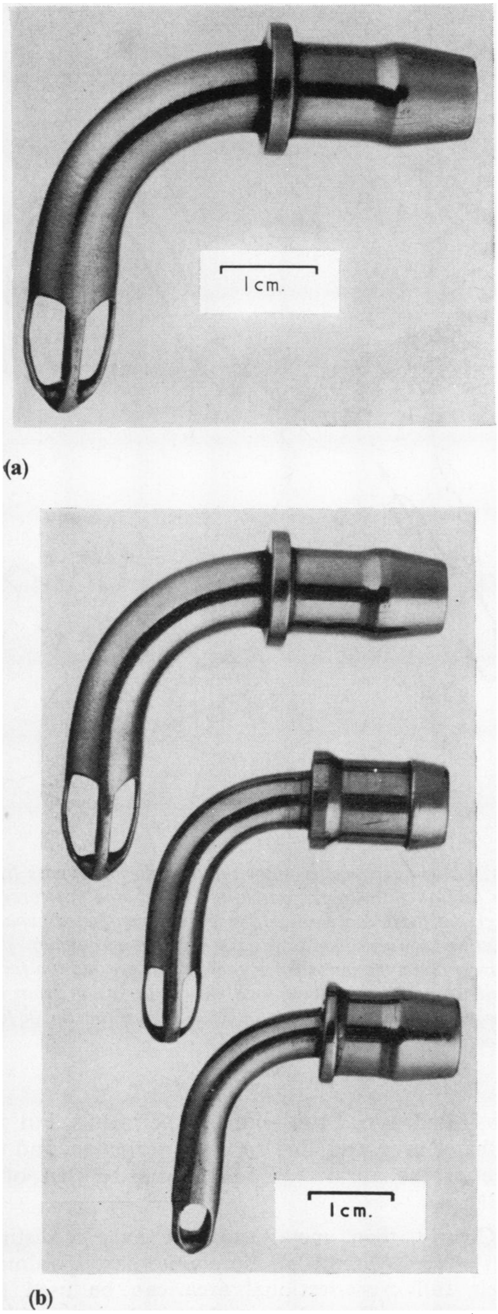

FIG. 1 (a, b). *A new design and range of cannulae for aortic arch perfusion.*

METAL CANNULA Arterial pressures were initially recorded with a standard femoral metal cannula perfusing via the aortic arch. For ease of insertion, a similar cannula, but with a right-angled bend at its mid-point, was likewise used in the aorta. The resulting arterial pressures were the same as for the straight femoral cannula. There was no difference in pressure between the left and right axillary arteries with either metal cannula as was seen with the plastic catheter. However, the pressure tracings (Fig. 3a) were easily produced by pointing the perfusing jet from either cannula towards the origin of an arch artery.

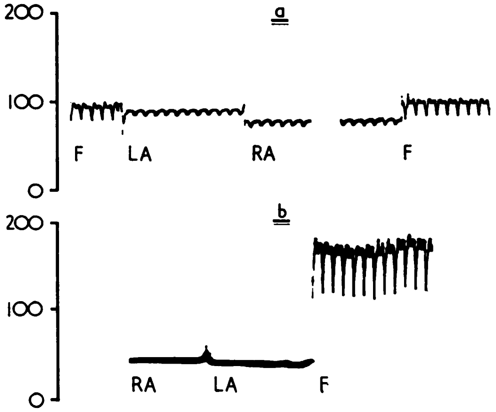

FIG. 2. *Pressure tracings during bypass, in 16-kg. dog, perfusing via the aorta with 4 mm. Simplastic catheter:* (a) *inserted 6 cm.;* (b) *inserted 25 cm. Pressures taken from femoral* (*F*), *left axillary* (*LA*), *and right axillary* (*RA*) *arteries.*

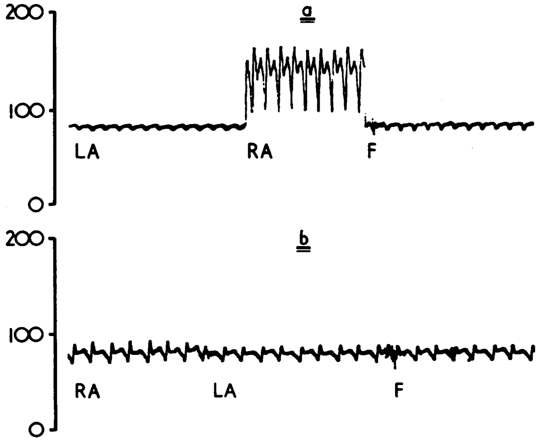

FIG. 3. *Pressure tracings during bypass in 16-kg. dog, perfusing with metal cannulae via the aorta:* (a) *right-angled, 4 mm. open-ended cannula pointing towards innominate artery;* (b) *right-angled cannula with new basket tip design pointing in same direction. Pressures taken from right axillary* (*RA*), *left axillary* (*LA*), *and femoral* (*F*) *arteries.*

By subsequent improvements to the perfusing tip of a right-angled metal cannula—namely, a blind ending tip with four laterally placed holes, preferential perfusion by the jet was abolished (Fig. 3b). This new design did not contribute to any increase in line pressure in the clinical flow range.

Flow patterns were observed at the catheter and cannula tip using the *in vitro* apparatus with dye in the perfusate. At the catheter tip, even with several small holes in the wall at the end, 95% of the flow passed through the open end as a single jet. If the open end was obstructed, the flow was diverted through the side holes, but at the cost of a dangerous rise in line pressure. No Venturi effect could be produced with either catheter or cannula.

DISCUSSION

From these results two fundamental perfusion problems emerge. The first is that there is inadequate perfusion in the aortic arch proximal to the tip of the catheter if the cross-sectional area of the infusing catheter, or cannula, is proportionately too large in relation to the size of the aortic lumen. Secondly, high-pressure preferential perfusion of an arch artery can arise with single jet perfusion.

Plastic catheters require a considerable wall thickness to be suitably rigid for perfusion (Galletti and Brecher, 1962). This compares unfavourably with the counterpart in metal. For a given internal diameter, the external diameter of a plastic catheter will be greater than that in metal. This increase in external diameter will result in a decrease in aortic lumen available for blood flow. To this point must be added the observation that plastic catheters tend to be inserted further than metal cannulae, and therefore are passing down the aorta, which is a narrowing tube (Fig. 4). The effect of this gave inadequate perfusion in the aorta proximal to the perfusing catheter tip, as shown by the drop in the axillary artery pressures and loss of wave form from the tracing (Figs 2a, b). That this was seen to a lesser degree when the catheter was inserted only the minimal correct distance is even more significant. It appears that the annular resistance to retrograde flow offered by the blood between the outside of the catheter and the aortic wall is in increasing proportion to the length of catheter within the aorta. Furthermore, as the plastic catheters exhibited single jet perfusion during the dye studies, they also showed differential perfusion of an arch artery. The results

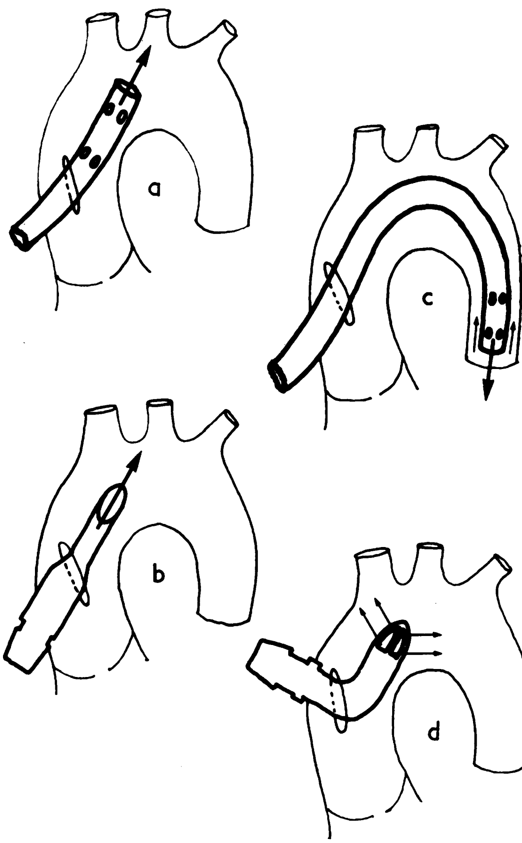

FIG. 4. *Illustrations to show the flow during bypass from the perfusing tip in the aortic arch:* (a) *and* (b) *forceful single jet perfusion from catheter and open-ended cannula pointing towards arch vessels;* (c) *predominant flow passing down the aorta when catheter is inserted too far in small aorta;* (d) *weaker multiple jet perfusion from the new metal cannula passing obliquely from the tip in four directions.*

illustrated were from animal experiments, but the catheter used was that for child perfusion, and the size of the aorta was comparable to that of a child.

Clearly, then, metal cannulae have a distinct advantage over the plastic counterpart, as almost their full cross-sectional area can be used for blood flow. Nevertheless, the single jet problem remained for the open-ended metal cannula until this was replaced by the four weaker jets of the new cannula. The resulting four weaker jets are illustrated passing obliquely from the new cannula tip, as compared with the forceful single jet of other methods (Fig. 4). Additionally, the new cannula acts as a bougie on insertion, by virtue of its tapering end.

I am indebted to Dr. E. Proctor for the design of the cannula and to Mr. T. Jones, who made a range of these cannulae, which have been used clinically with success. I am grateful to Lord Brock, who suggested this investigation, and for his constant encouragement.

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