Technical Papers

Revascularization of the Heart by a Pedicle Skin Flap

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This is a preliminary report on a series of experiments carried out in dogs for the purpose of developing a new blood supply to the myocardium by means of a skin flap.

One of the authors (R. E. M.) observed several years ago an unusual property of pedicle flaps during an attempted transplantation of a flap from one individual to another. The flap was a delayed tubed flap, transferred between individuals who were close blood relatives and whose blood types were identical. On the fourth day following transplantation the donor developed signs of shock and anemia. It became apparent that a large volume of the donor's blood was being transferred to the circulation of the recipient through the tube, and, despite multiple transfusions in the opposite direction, the donor developed a severe anemia and the recipient a severe polycythemia which necessitated division of the tube. The volume of blood which this tube was capable of transporting suggested that a flap of skin and subcutaneous tissue might prove successful as a vehicle to carry a new blood supply to the heart. To our knowledge a skin flap has never been used for this purpose.

Accordingly, we embarked on a series of experiments with the purpose of finding out whether the operation was possible and, if so, how high a mortality it would entail. Second, we hoped to demonstrate whether anastomoses occur between the blood vessels in the flap and those in the heart. And third, if anastomoses could be demonstrated, we wished to discover whether a sufficient volume of blood could be carried by the flap to protect the heart against occlusion of a coronary artery.

Twenty-five dogs have been studied to date, in trying different techniques of constructing and attaching the flap and using a number of methods to evaluate its effect. The animals averaged 18 kg in weight. The type of flap we have found most useful is a single pedicle flap, raised and implanted in one stage. The operation consisted of elevating a thoracoabdominal flap, based over the fifth or sixth ribs near the apex of the heart. A segment of the sixth rib was removed to provide room for passage of the flap through the chest wall, and the proximal portion of the flap was tubed so that the tubed part of the flap extended the entire distance between the chest wall and the heart. The remaining open portion of the flap was then passed through an incision in the pericardium, sutured directly to the myocardium over the apex, and the chest was closed firmly about the tube. The epithelium of the tube was not disturbed. The reason for tubing that portion of the flap between the chest wall and the heart and not removing the secretory elements of the epithelium was to produce as critical an experiment as possible by excluding all sources of blood supply other than that which passed directly through the pedicle. The flaps averaged 16 cm in length by 9 cm in width at the base, tapering toward the distal end and varying somewhat in size with the size of the animal. This allowed us to cover approximately one third the area of each ventricle with the open portion of the flap, so that areas of myocardium supplied by all the coronary vessels had access to the vessels of the flap.

No deaths occurred directly as a result of attaching the flap. Two animals died during the operative procedure, but both deaths were the result of anesthetic accidents. Postoperatively the dogs appeared healthy and normal for periods up to 6 months following the operation.

The flap produced no apparent effect on cardiac function. No constriction of the heart occurred, and although the heart was rotated in a few cases as a result of a somewhat short pedicle, no demonstrable interference with its mechanical function resulted. Little inflammatory reaction occurred in the portion of the pericardial cavity not covered by the flap, for the pericardium rapidly became attached to the edges of the flap, preventing escape of skin secretions into the free pericardial cavity.

No dog developed either a pneumothorax or an empyema. When the animals were sacrificed it was found that the tube had become completely walled off from the free chest cavity by adherent lung, and that sinus tracts had developed along the tube from the pericardial cavity to the surface through which the secretions of the tube drained.

The changes observed in the electrocardiogram followed a definite pattern. Immediately following the operation, depression in voltage and changes in the QRS complexes appeared, which resulted partly from positional changes of the heart. These soon disappeared, but by the fourth or fifth week progressive changes appeared in the T waves, with elevation of the ST segments which simulated the changes seen in pericarditis.

To demonstrate the presence of anastomoses between the vessels of the flap and those of the myocardium, several methods were used.

Employing a specimen removed from one of the early animals a cannula was inserted in the descending ramus of the left coronary artery and 35% diodrast and gentian violet were injected under a pressure of 70 mm Hg. The colored dye was seen to drip from the cut end of the pedicle and the radiopaque

medium was demonstrated in the vessels of the tube by x-ray.

A second method was based on the premise that if good anastomoses were present between the vessels of the flap and those of the heart, they might carry sufficient blood to support the tube with its pedicle divided. Accordingly, in an animal with a flap implanted for one month, the base of the pedicle was completely transected so that its only source of blood was through the surface of the flap attached to the heart. Arterial blood spurted from the distal cut surface of the tube, and one week later, when the animal was sacrificed, the tube appeared viable, with healthy granulations on its cut surface.

In another animal we observed direct evidences of anastomoses during a secondary operation, 1 month after a flap had been applied. The descending ramus of the left coronary artery was dissected out, ligated, and divided distal to the ligature. The distal cut end of the vessel spurted arterial blood which must have come either through the pedicle or from one of the other coronary arteries with the flap acting as a bridge.

In order to demonstrate the anastomoses visually, a method was developed by which radiopaque material could be injected through the vessels of the tube. The injection medium used was a 20% aqueous suspension of bismuth oxychloride, which has a particle size too large to pass through the capillaries, and will not pass through arterioles smaller than 35 or 40 μ in diameter. The technique consisted of isolating the coronary vessels by ligating the aorta immediately distal to their origin. The segment of aorta whose branches supplied the left chest wall and the vessels of the flap was then isolated by ligating the descending thoracic aorta above the diaphragm, and the injection was carried out through this segment under a pressure of 220 mm Hg. The injection mass flowed through the vessels of the chest wall into the vessels of the tube and then passed through numerous anastomoses to fill the coronary vessels. None of the injection medium was found in the veins because the bismuth could not pass the capillary barrier. Since the injection medium found in the coronary vessels was derived from the flap, the anastomoses were demonstrated to be at least arteriolar in caliber (Fig. 1).

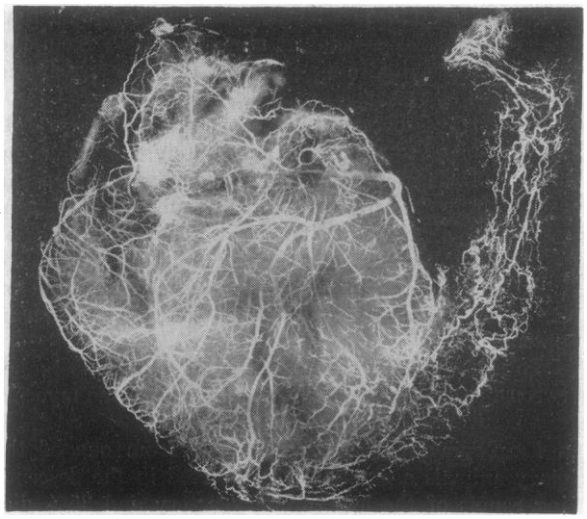

FIG. 1. X-ray of a heart to which a flap had been attached for 1 month, injected by method described in text. All the bismuth seen in the coronary arteries passed through the pedicle.

The experiments carried out so far have demonstrated that a skin flap may be attached to the heart without harmful sequelae, and that macroscopic anastomoses occur between the vessels of the flap and the coronary arterial circulation of the heart. Although three animals protected by a flap have had the descending ramus of the left coronary artery ligated without mortality, the series is too small to be significant, and further studies are under way to establish whether the flap carries a sufficient volume of blood to protect the heart against coronary occlusion.

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Abnormal Growth and Fructification of the Cultivated Mushroom

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Since the seventeenth century it has been customary to induce the development of the mushroom fruiting bodies, or sporophores, by covering the surface of mycelium-impregnated compost with a layer of loam about 1 in. deep. The function of this layer of soil in initiating fructification of the cultivated mushroom *Agaricus campestris* L. has never been proved experimentally. A study of abnormal growth may provide the entering wedge for understanding this function.

The stems of mushrooms growing on beds sometimes elongate abnormally, and at the same time, the growth of the caps is retarded. Lambert (*1*) claims to have demonstrated experimentally that this abnormal growth is due to the injurious effects of carbon dioxide released during respiration of sporophores. An evaluation of his results reveals, however, that there is slight, if any, elongation of the stem when the CO_2 introduced under the bell jars is derived from commercial cylinders; whereas severe abnormal growth occurs if the gases accumulate from respiration. It appears that in the gases accumulating naturally there may be another volatile substance which is responsible for this abnormal growth.

In this paper, an attempt is made to demonstrate that an elongation of the stem and retardation of the cap may occur even in the complete absence of carbon dioxide. The device employed to investigate this point (*2*) was a bell jar with two openings, one in the top and the other in the side at the bottom (Fig. 1, No. 3). When this kind of bell jar was placed over mushrooms

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