A COMPARISON OF OPEN-CHEST AND CLOSED-CHEST CARDIAC MASSAGE IN DOGS

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RECENTLY a method of cardiac massage was reported which consisted of rhythmic compression of the heart between the sternum and vertebral column.[1] In cases of cardiac arrest the advantages of avoiding thoracotomy under the most urgent and usually septic conditions are obvious. Certainly a technique of cardiac massage which does not require thoracotomy would be more widely applicable than the presently accepted method. However, when cardiac arrest occurs under conditions that permit thoracotomy, will use of the new method of closed-chest cardiac massage result in less effective artificial circulation? Will vigorous compression of the sternum against the vertebral column result in trauma more severe than thoracotomy?

The ultimate evaluation of a resuscitative technique, of course, depends upon its effectiveness in salvaging patients. The difficulty in distinguishing between profound hypotension and true cardiac arrest and in determining the differing degrees of salvagability encountered in patients led us to devise an experiment in dogs whereby the two methods could be compared under identical conditions.

METHODS

Twenty healthy mongrel dogs weighing between 6 and 12 kg. were anesthetized with intravenous pentobarbital sodium (25 mg./kg. body weight). In each instance an endotracheal tube was inserted and the cuff inflated. Each dog was secured in the supine position and intermittent positive pressure ventilation was begun utilizing room air at a rate of 20 inflations per minute and with tidal volumes of 25 ml./kg. body weight. The chest of each dog was shaved. A polyethylene catheter (outside diameter—1.7 mm.) was passed through a femoral artery into the aorta and was connected to a strain gauge transducer. Electrodes for recording the electrocardiogram were attached to all four extremities. Aortic pressure and electrocardiogram were recorded continuously through appropriate amplifiers on a Sanborn direct writing recorder. A bubble flowmeter was improvised in the following manner. A carotid artery was isolated. One end of a polyethylene catheter (outside diameter—4.0 mm.) filled with heparinized saline was inserted proximally into the lumen of the artery and the other end of the catheter was inserted distally. The catheter was calibrated to contain a volume of 2.0 ml. After each dog had received intravenous heparin, 4 mg./kg. body weight, the entire blood flow of the carotid artery was diverted through this improvised flowmeter. With a tuberculin syringe 0.04 cc. of air was injected into the proximal end of the flowmeter, and the passage of the air bubble was timed for a distance known to represent a volume of 2.0 ml. of blood.

Thirty minutes were allowed after the injection of the anesthetic to permit the vital signs to reach equilibrium. Then, in order to produce ventricular fibrillation in each of the 20 dogs, the electrodes of a Birkmire defibrillator were applied to the chest wall. An electrical shock of 110 volts and 1.5 to 3.0 amperes was given for 5 seconds.

Thirty seconds after the onset of ventricular fibrillation in 10 of the dogs, closed chest cardiac massage was begun by compressing the sternum against the vertebral column five times following each lung inflation. Since the lungs were inflated twenty times per minute, the resulting artificial heart rate was 100 beats per minute. This combination of intermittent positive pressure breathing and closed chest cardiac massage was continued for twenty minutes. At the end of this time the electrodes of a Kouwenhoven external defibril-

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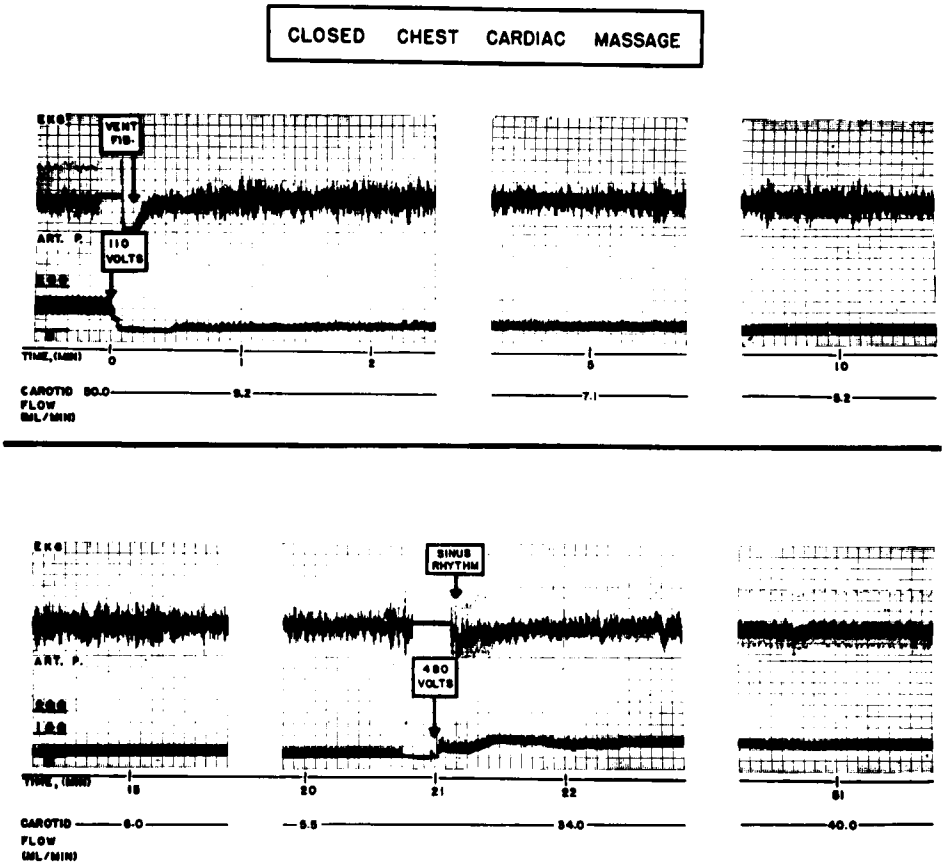

FIG. 1. Successful restoration of circulation following twenty minutes of closed chest cardiac massage in a dog suffering ventricular fibrillation.

lator [2] were applied to the chest over the manubrium sternum and over the apex of the heart, and a 480 volt shock was administered for 0.25 seconds.

In the remaining 10 dogs, following the onset of ventricular fibrillation, a thoracotomy was performed immediately through the fourth left intercostal space. Manual compression of the ventricles was begun, the pericardium was opened after one minute, and massage was continued for a total of twenty minutes. The electrodes of the Birkmire internal defibrillator were then applied to the ventricles and an electric shock of 110 volts was given for 5 seconds.

In each group the carotid blood flow was determined just before the initiation of ventricular fibrillation; after 1, 5, 10, 15 and 20 minutes of ventricular fibrillation; and 1 and 30 minutes after defibrillation of the ventricles.

RESULTS

In a series of preliminary trials it was found that carotid blood flows determined with our improvised flowmeter were highly reproducible and that air introduced into the carotid circulation in volumes comparable to those used in our experiments had no detectable influence on the carotid flow.

With each of the 20 dogs receiving intermittent positive pressure breathing with room air just prior to the start of the experiment, the carotid blood flows were found to be from 17 ml./minute to 60 ml./minute while aortic pressures ranged from 100/70 mm. of mercury to 170/130 mm. of mercury. Ventricular fibrillation developed in each animal immediately upon the application of the 110

volt shock to the chest wall and in each case the blood pressure fell immediately to zero.

In the 10 dogs treated with closed chest cardiac massage (fig. 1) aortic pressures ranged from 35/0 mm. of mercury to 80/35 mm. of mercury in the first minute, and the carotid blood flows were from 2.7 ml./minute to 15 ml./minute. The average carotid flow (fig. 3) of each dog throughout the twenty-minute period of massage was from 7 to 19 per cent of the control value. During the same period average aortic pressures (fig. 4) were from 22 to 39 per cent of control. Nine of the 10 dogs reverted to a sinus rhythm immediately following the administration of the 480 volt shock to the precordium. In the single instance where defibrillation was not accomplished initially, continued massage and the intravenous injection of 0.8 ml. of adrenalin 1:1,000 solution, followed by a second shock, successfully restored a spontaneous circulation. One minute after restoration of circulation in each of the animals the carotid blood flows were from 50 to 167 per cent, and after thirty minutes from 40 to 100 per cent of control.

In the 10 dogs treated with thoracotomy and manual systole (fig. 2) from 25 to 52 seconds were required after the development of ventricular fibrillation to perform the thoracotomy and initiate manual systole. During the first minute of massage, with the pericardium unopened, aortic pressures ranged from 35/15 mm. of mercury to 100/50 mm. of mercury and carotid flows of from 5 ml./minute to 13 ml./minute were recorded. Throughout the twenty minute period of massage the average carotid flow in each dog was from 7 to 43 per cent of the control value, while the average aortic pressure was

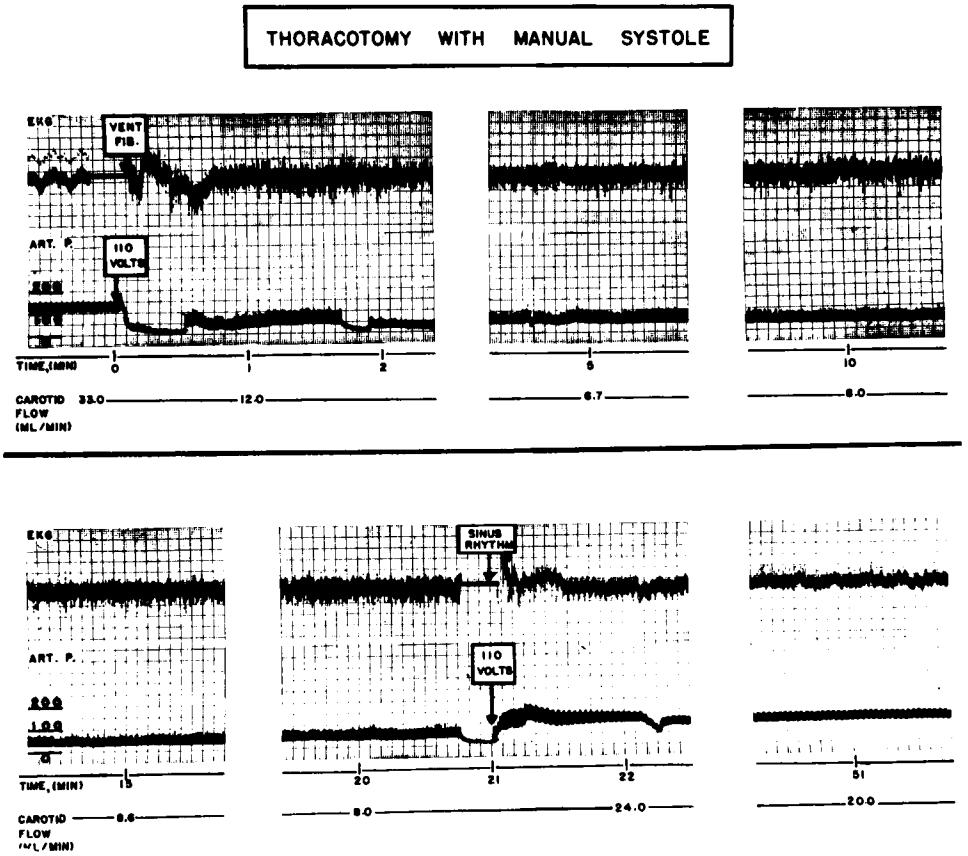

FIG. 2. Successful restoration of circulation following thoracotomy and twenty minutes of open chest cardiac massage in a dog suffering ventricular fibrillation.

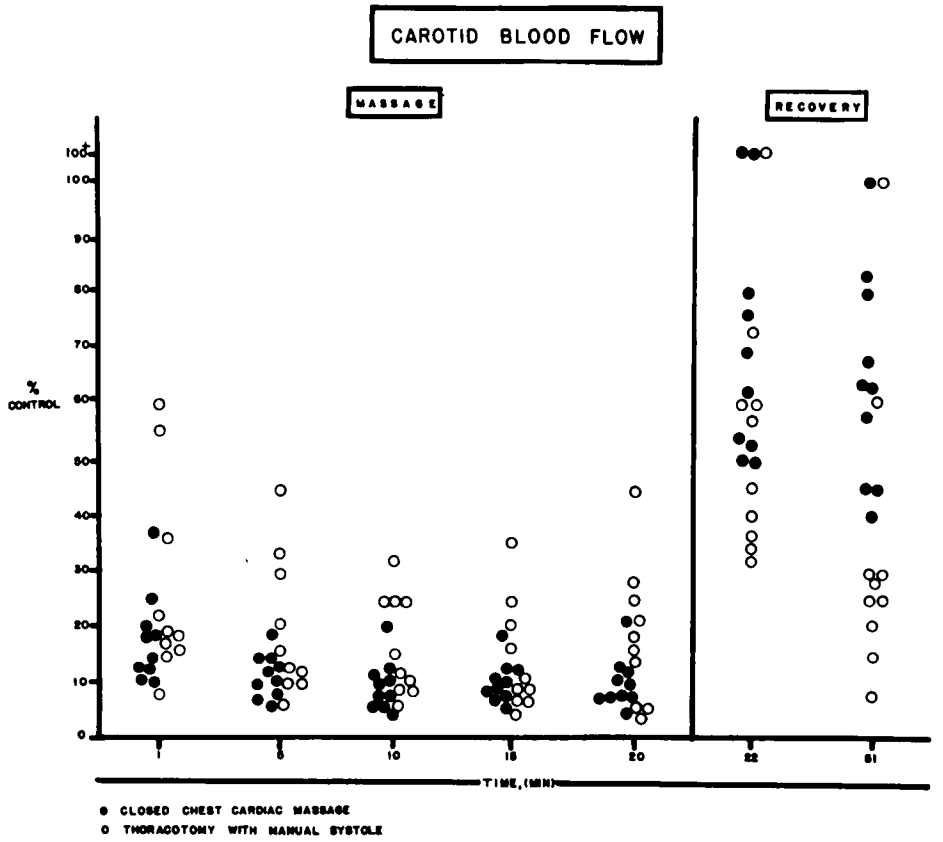

FIG. 3. Carotid blood flow determinations in 20 dogs with ventricular fibrillation, 10 treated with closed chest and 10 with open chest cardiac massage.

from 19 to 71 per cent of control. Each of the 10 dogs reverted to a sinus rhythm immediately following the administration of the 110 volt shock to the ventricles. In one of them an intravenous injection of 0.8 cc. of adrenalin solution (1:1,000) and continued massage were required to re-establish a recordable blood pressure. One minute after restoration of circulation in each of the animals the carotid flows ranged from 33 to 118 per cent, and after thirty minutes from 7 to 100 per cent of control.

DISCUSSION

Since there is considerable difference between the canine and human thorax, our findings in regard to the trauma of closed chest cardiac massage in dogs selected at random may not be applicable to human resuscitation. In over forty pilot experiments we found that severe trauma resulted when we exerted maximal force in an attempt to obtain the highest possible blood pressure during massage. Mediastinal hemorrhage, fractured ribs and lacerations of the liver were encountered frequently. During these pilot experiments we found that survival most often followed the use of moderately forceful compression of the sternum. In this study there was almost invariably distortion of the chest contour after closed chest cardiac massage, chiefly due to fractures of the costal cartilages.

As the study progressed it became evident that there was a striking difference between the methods as far as fatigue of the operator was concerned. One of us was easily able to continue closed chest cardiac massage for a twenty minute period. However the

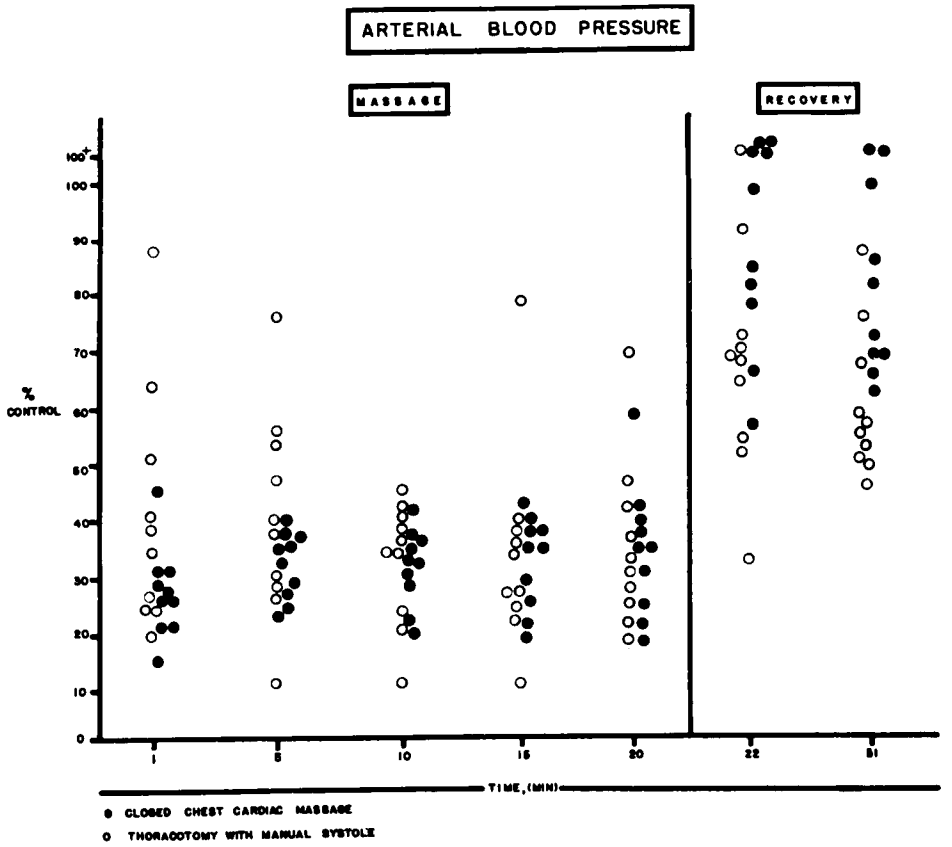

FIG. 4. Aortic blood pressures recorded in 20 dogs with ventricular fibrillation, 10 treated with open chest and 10 with closed chest cardiac massage.

fatigue resulting from manual compression of the ventricles made it necessary to use more than one operator during the twenty minutes of massage.

We were also impressed by the rapidity with which thoracotomy could be performed. Artificial circulation was established very rapidly with either method.

Most cases of cardiac arrest in humans result from asphyxia and were not simulated in this experiment. It is of interest to note that we have used this technique of closed chest cardiac massage in the successful resuscitation of dogs subjected to severe obstructive asphyxia followed by flooding of the lungs with fresh water resulting in ventricular fibrillation (unpublished data). Evidently the circulation produced by closed chest cardiac massage combined with intermittent positive pressure breathing is adequate to reoxygenate the myocardium in cases of severe asphyxia.

Although we do not believe that our measurements represent true blood flow through the intact carotid artery, we feel that our method is sufficiently accurate to permit a comparison of the flows obtained by the two methods of cardiac resuscitation. Carotid flow determined fifty times during closed chest cardiac massage of the fibrillating heart in these experiments averaged 12 per cent of the control flow determined prior to the production of ventricular fibrillation. During manual compression of the ventricles after thoracotomy the average of 50 determinations of carotid flow was 19 per cent of control. Aortic blood pressure recorded simultaneously during closed chest cardiac massage averaged 31 per cent of control and during manual systole 37 per cent of control. It would

seem that within the limits of the experimental method the artificial circulation produced by closed chest cardiac massage was comparable to that produced by thoracotomy and manual systole. The apparent difference in circulation after defibrillation may have been due to bleeding in the thoracotomized animals.

SUMMARY

In dogs suffering cardiac arrest by ventricular fibrillation:

The artificial circulation produced by closed-chest cardiac massage approximated that produced by open-chest cardiac massage.

Circulation was effectively restored after application of either method.

Trauma with closed-chest cardiac massage was minimal when only moderate force was applied to the chest.

Closed-chest cardiac massage was much less fatiguing to the operator.

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INTRAOSSEOUS ANESTHESIA Intraosseous pelvic anesthesia was used in 20 patients during operations of the prostate, bladder and urethra. After anesthesia of soft tissues the needle-trocar is inserted to a depth of 1.5–1.8 cm. into the spongy part of the iliac bone 1.5–2 cm. behind the spina iliaca anterior superior. After removal of the mandrin the procaine solution is introduced into the bone marrow. The anesthesia is up to 3 hours in duration. (*Salaida, N. A.: Intraosseus Pelvic Anaesthesia in Urological Operations and its Anatomical Basis, Urologiya 5: 39, 1959.*)

EPIDURAL CORTISONE Sciatic pain was benefitted in more than half of 239 patients who received injections into the caudal canal of a solution of procaine and hydrocortisone acetate. Many patients had one or more laminectomies before this therapy was begun. Eight patients who had a return of symptoms after 3 months received relief from a second series of injections. The results are attributed to reduction of inflammation, edema and adhesions around the nerve sleeve. (*Goebert, H. W., Jr., and others: Sciatica: Treatment with Epidural Injections of Procaine and Hydrocortisone, Cleveland Clin. Quart. 27: 191 (Oct.) 1960.*)

INTRADURAL CORTISONE Thirty-six patients who had not had their sciatic pain relieved by various other treatments were given subarachnoid injections of cortisone type drugs. Roughly one-third obtained complete relief, one-third obtained 50 per cent relief, and one-third obtained little or no relief. Corticosteroids reduce congestion and inflammation. (*Sehgal, A. D., and Gardner, W. J.: Corticosteroids Administered Intradurally for Relief of Sciatica, Cleveland Clin. Quart. 27: 198 (Oct.) 1960.*)