In recent years, remarkable advancement has been made in cardiac resuscitation, and clinical data indicate that the resuscitation rate has been greatly improved. This advancement can be attributed to the introduction of the closed chest cardiac massage (CCCM), which marks an epoch in resuscitology.

However, CCCM must be administered by well trained individuals to preclude the development of complications, such as rib and sternal fractures, bone marrow emboli, liver or spleen lacerations. In the case of an obese patient, particularly one with a thick thorax, this technique may be inadequate to provide sufficient flow of blood to the brain. In such cases, should brute force be applied, in an attempt to obtain satisfactory efficacy, the aforementioned complications are unavoidable.

The author has attempted to develop a technique that will furnish the efficacy of the CCCM but does not require the violent force necessary to depress the sternum. Furthermore, the author developed a new technique of cardiac resuscitation through the oesophagus by inflating a balloon rhythmically which was inserted an appropriate level of the oesophagus behind the heart. The balloon was connected by a thick-walled long tube to another balloon that was placed on the sternum. Thus, the combined technique of CCCM was accomplished from both sternal and oesophageal side by depressing the balloon on the sternum and concomitantly inflating the balloon in the esophagus.

The purpose of this study is to determine whether the new technique would be sufficient to support CCCM without the need for violent force which can cause severe complications.

METHODS

Thirty-five well-nourished adult dogs, weighing between 7.2 and 13.5 kg were lightly anesthetized with Thiamylal, 25 mg/kg administered intravenously, and their tracheae were intubated with a cuffed endotracheal tube. A catheter was inserted through a femoral artery into the aorta for monitoring the aortic blood pressure, and another catheter was used to bypass the carotid artery to monitor the carotid blood flow. Lead number 2 of the electrocardiogram was recorded continuously.

Each animal was secured in the supine position. While they were breathing spontaneously, the endotracheal tube was clamped at the end of an exhalation, to assure
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acute asphyxia. Total circulatory arrest was confirmed by the cessation of flow in the carotid arteries and by the result of ECG.

A period of one minute was allowed to elapse between the completion of circulatory arrest and the initiation of resuscitation. Intermittent positive pressure breathing with 100% of oxygen was administered at a rate of 20 breaths per minute and tidal volumes of 25 ml/kg body weight. CCCM was initiated concurrently with five compressions of the sternum during each exhalation.

Fig. 1

Fig. 2
The force required for compression of the sternum was regulated to a certain percent of the ventrodorsal diameter of the thorax by use of the compression machine using the principle of the lever and fulcum.

The animals were divided into two groups: one receiving the original technique of CCCM and the other receiving the new technique of CCCM.

The anatomical situation of the heart, diaphragm and oesophagus of the dogs are shown in Figure 1 and the inflated balloon in the oesophagus is shown in Figure 2. Drugs were not used during the cardiac resuscitation tests.

RESULTS

The CCCM and artificial ventilation produced 35 to 50 percent of a control value of the systolic pressure of the femoral artery before the acute asphyxia was loaded, and 7 to 20 percent of the carotid blood flow when the force was regulated by the compression machine and maintained at a certain strength of the sternal compression (35% of ventro-dorsal diameter of the thorax).

When the artificial ventilation was instituted by the new technique of CCCM, which was performed by the rhythmic compression of the balloon on the sternum so that the other balloon would be concomitantly inflated, the efficacy of the original

![Graph comparing blood pressure and carotid blood flow](image)

**Fig. 3** Comparisons of the level of the blood pressure of femoral artery and the carotid blood flow obtained by two kinds of techniques of closed chest cardiac massage.

CCCM: The original technique of closed chest cardiac massage

CCCM & ECM: The closed chest cardiac massage with an adjuvant cardiac massage through the oesophagus behind the heart.
Fig. 4 Various strength of sternal compression and comparisons of circulatory efficacies obtained by two techniques of closed chest cardiac massage.

**CCCM**: The original technique of closed chest cardiac massage

**CCCM & ECM**: The combined technique of CCCM with the adjuvant cardiac massage through the oesophagus behind the heart.

**E.C.G.**: Electrocardiographic tracings during cardiac massage

**B.P.**: Blood pressure of femoral artery

**B.F.**: Carotid blood flow rate
Technique of CCCM was greatly improved. It was sufficient to obtain 45 to 75 percent of a control value of the systolic pressure of the femoral artery and 15 to 30 percent of the carotid blood flow. (Fig. 3.)

Figure (4) demonstrates the changes in blood pressure, carotid blood flow, and ECG which were obtained by the cardiac resuscitation of the cardiac-arrested dogs with various strength of sternal compression (30 to 50 percent of ventrodorsal diameter of the thorax), and presents the variation in the efficacies between the original technique of CCCM and the modified method.

In Figure (5) and (6), the level of systolic blood pressure and carotid blood flow obtained during CCCM.
which were artificially produced by the CCCM can be positively interrelated with the degree of compression power to the sternum. Thus, when greater pressure was applied to the sternum, a higher level of the systolic blood pressure was obtained.

In Figure (5) and (6), the solid lines depict the correlation between the level of systolic pressure and carotid blood flow which were obtained by the new technique of CCCM and the degree of the strength of sternal compression, while the dotted lines depict that of the original technique of CCCM.

These results indicate that the new technique of CCCM would require less pressure on the sternal compression to obtain the higher level of blood pressure and carotid blood flow as compared to that of the original technique. Besides, as shown in the Figure (5) and (6), the relation between the degree of the applied force and the obtained level of systolic blood pressure is depicted by a logarithmic curve, while the relation between the degree of force and the carotid blood flow is depicted by the curve of second degree.

Therefore, it is presumed that larger amount of carotid blood flow rather than the higher level of blood pressure may be obtained, if greater pressure is applied to the sternum.

However, this high efficacy of the new technique was greatly reduced when the balloon in the esophagus was maintained in an inflated state instead of inflating it rhythmically and concomitantly with the sternal compressions.

Figure (7) illustrates that the period of time from the onset of acute asphyxia to the occurrence of cardiac arrest, as detected by ECG and an electromanometer, would be interrelated with the period of time for the circulation to be favourably restored after the combined performance of CCCM with artificial ventilation, which is exactly one minute after the occurrence of cardiac arrest.

The duration required for the restoration of circulation with the new technique of CCCM was much shorter than that of the original technique as indicated in Figure (7).

![Fig. 7](image_url)

*Fig. 7* The time up to the restoration of circulatory arrest from the institution of cardiac massage and the time up to the circulatory arrest from the onset of asphyxia,
DISCUSSION

Without a doubt the development of closed chest cardiac massage has contributed much toward the saving of many lives. Its use can be amplified, if the closed chest cardiac massage can be performed easily and immediately, requiring minimum of training for efficient application.

However, this technique would be frequently less effective than the open cardiac resuscitation, particularly, in the case of obese patients who have thick thorax and may result in rib or sternal fractures in the aged patients whose cartilages of the thorax may be almost calcified.

Therefore, it should be significant that the new technique, which would require less pressure on the sternum while providing adequate artificial circulation be developed. The indirect cardiac massage via the esophagus seemed to have achieved this aim, for the author's technique of closed chest cardiac massage required about thirty percent less pressure of sternal compression to obtain the same degree of the blood pressure and the blood flow as that of the original technique. The level of the blood pressure which was obtained during the CCCM was raised in proportion to the force applied to the sternum. However, the degree of increase in the obtained blood pressure was not so remarkable as that of the blood flow, even though more powerful compressions were applied.

Thus, one cannot expect to obtain the favorably high level of blood pressure, but is able to increase the blood flow, by applying greater pressure on the sternum.

The efficacy of the new technique of closed chest cardiac massage presents the possibility of obtaining sufficient blood flow with less force required to depress the sternum.

This new technique of closed chest cardiac massage with the oesophageal approach should be subjected to clinical investigation, since many problems, such as the time which required for the insertion of the balloon to the appropriate level of the oesophagus and the air way problem remain to be investigated by clinical cases.

SUMMARY AND CONCLUSIONS

A new technique of the closed chest cardiac massage which is performed by rhythmically inflating a balloon at the appropriate site of the oesophagus behind the heart has been experimentally proven to be an excellent adjuvants to the closed chest cardiac massage in restoring circulation, especially carotid blood flow after circulatory arrest.

A higher level of the systolic blood pressure and blood flow was obtained by inflating the balloon rhythmically and depressing the hemispherical balloon concomitantly which is placed on the lower third of the sternum, in comparison with the original technique of the closed chest cardiac massage.

The new technique required about 30 percent less (on the average) pressure of sternal compressions, as compared to the original technique.

The excellent efficacy of the new technique of closed chest cardiac massage cannot be expected when the balloon in the oesophagus is kept inflated instead of inflating it rhythmically and concomitantly with the sternal compressions.
REFERENCES


