Fundamental Studies on Maintenance of the Circulation in Cardiac Asystole by the Mechanocardiac Pulsator*

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Cardiac asystole which manifests itself as a ventricular fibrillation or cardiac standstill is an accident occurring in approximately 0.1 per cent of all surgical interventions. It has been reported that 87 per cent of cardiac arrests occur in the operating room.

In many medical institutions of the world, the customary approach to the problem is time consuming and conservative. All too frequently transparietal intracardiac injections of analeptics are used and are nearly always unsuccessful. If by chance they do restore heart function, it is doubtful as to whether the heart was in arrest in the first place. The alternative approach which is gaining popularity with surgeons with respect to cardiac resuscitation is that heart massage should be the exclusive treatment. In the event of a mistaken diagnosis of cardiac asystole, the intervention would still be justified as the better choice of two evils. Unfortunately, it is not always possible to restore adequate circulation of the blood before anoxia has done irreparable damage to the brain. It is now universally accepted that the critical time period whereby circulation can be detained without permanent damage to the central nervous system is four minutes. Statistical studies done by various authors concerning this time rule has proved that survival with or without neurological sequelae is above 80 per cent when the circulation has been promptly restored. Failing to restore circulation within this time limit brought the survival rate down to approximately 30 per cent, mortality increasing for every extra minute of time that was delayed.

It is understood that survival is not assured even when massage is done within the four-minute period. There are numerous factors which will determine the outcome of cardiac massage, such as the state of the heart itself, whether it be in failure, intoxicated by overdosage of anesthetics, anoxia, etc. Furthermore, the technique of the operator doing the massage and the maintenance of adequate blood pressure by intravenous infusions of vasoconstrictors should be given consideration.

The object of this paper is to study primarily the methods of heart massage and to give some thought concerning the use of vasoconstrictors and plasma expanders as ancillary agents to maintain adequate blood flow during cardiac asystole.

The primary cause for inadequate blood flow during manual massage is incorrect technique and fatigue of the operator. This sufficed to justify a study of the alternative possibilities to overcome the varying performance of the human factor in play. To this purpose cardiac mas-

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FIGURE 1A: Key to abbreviations: (Contr.) controls; (Man. M.) manual massage; (Can.) rubber flanged canulla; (Bal. I) balloon; (Bal. II) mantled balloon. Graphic results of the systemic arterial pressures obtained in 28 mongrel dogs weighing 10-16 kilos during cardiac compression compared with their original control values. Above are shown systolic pressure variations. In the middle: average systolic, mean and diastolic pressures. Below are the diastolic pressure variations. Note improved pressures in Bal. I and Bal. II compared with those in manual massage and canulla experiments.

FIGURE 1B: Key to abbreviations: (see Fig. 1A). Graphic results of the pulmonary artery pressures obtained in the same way as described in Fig. 1A. Above are shown systolic pressure variations. In the middle: average systolic, mean and diastolic pressures. Below are the diastolic pressure variations. Note above the high range of systolic pressure variations in the canulla experiments, with (middle) an average mean below that of the control. Note also the high pulmonary artery mean with manual massage.

FIGURE 1C: Key to abbreviations: (see Fig. 1A). Graphic results of the pulmonary vein pressures obtained in the same way as described in Fig. 1A. Above are shown systolic variations. In the middle: average systolic, mean and diastolic pressures. Below are the diastolic pressure variations. Note the comparatively low systolic variations of pressure with manual massage and the balloons. Note also that the average systolic pressures with manual massage and in the experiments done with Bal. II were much lower than those obtained with the canulla and Bal. I.
sage by mechanical means had stimulated the endeavors of two research teams outside of this country\textsuperscript{14} apart from our own.

It was considered worthy of speculation to further the studies reported by Bencini and Parola on pneumomassage of the heart. Particular emphasis was to be placed on the study of the hemodynamic response in the systemic and pulmonary circulation with a purpose in view of making possible technical improvements.

\textit{Experimental Methods}

The general outlay for experimentation was divided into three parts: a) to continue studies on pneumomassage of the heart; b) experimentation on heart compression by the intermittent inflation of a balloon in the pericardial sac placed behind the left ventricle; c) similar experiments with a balloon included in a mantle of nylon cloth; d) experiments on manual heart massage to compare with experiments A, B, and C.

A new apparatus was designed to obtain intermittent positive pressure by the use of a Y tube or modified Venturi tube with the addition of a pop-off valve, closed intermittently by a cam rotating on a shaft driven by an electric motor (Figs. 2A, and 2B). The cycles of pressure were so regulated by the adjustable cam as to produce a one-third positive or systolic and a two-thirds negative or diastolic phase, the latter having a negative pressure of $-3$ to $-5$ mm. Hg.

A cannula with a circular rubber flanged end (Figs. 3D, and 3D\textsuperscript{1}) was devised for inflating the pericardial space.

Introduction of the cannula into the pericardial sac was made easier by raising the pericardium from the myocardium by suction. This was done with a double-walled stainless steel tube (Figs. 3C, and 3C\textsuperscript{1}) with the intermural space connected to a vacuum pump via a side arm. The suction end was then applied to the pericardium through the central lumen of the suction tube and a stainless steel tube was passed with a circular hollow ground cutting edge at one end (Figs. 3E, and 3E\textsuperscript{1}). Alternating rotary movements cut out a round piece of pericardium. The cutting tube was then withdrawn and the lubricated cannula introduced flange forward down the lumen of the sucker tube (Figs. 3C, and 3C\textsuperscript{1}) until the flange spread out under the pericardium securing the cannula in place. The opposite end of the cannula was then attached to a polyethylene tube connected to the Venturi tube. The air pressure in the cannula intermittently inflated the pericardial sac and was transmitted to the walls of the heart collapsing the chambers, thus causing the blood to flow into the systemic and pulmonary circulation.

In this paper, a total of 55 experiments on mongrel dogs were done and distributed in the following order: (A) 36 with the cannula (pneumomassage); (B) 7 with a balloon placed behind the left ventricle within the pericardial sac; (C) 8 with a mantled balloon placed as in B; (D) 4 with manual compression.

\textit{Experimental Procedure}

Positive pressure ether-oxygen anesthesia was used for these experiments. Thoracotomy was done through the fifth interspace on the left or right side. The femoral artery, pulmonary artery and pulmonary
vein were catheterized with #P190 polyethylene tubing linked up to P23D strain gauges. All pressures were monitored on a five-channel Grass Polygraph recorder (Fig. 5). Cardiac asystole was produced with an electrical fibrillator-defibrillator apparatus, using 100 volt A.C. for fibrillation and 150-volt A.C. for defibrillation after completion of the experiment (Fig. 4). A venous cutdown was done in practically all the experiments for the infusion of vasoconstrictors and plasma expanders. During pumping, the ether was cut off and the dog received only oxygen by positive pressure respiration.

Experimental Results

(A) Pneumomassage of the heart. Thirty-six experiments were made in this group. To maintain an adequate systemic pressure it was found that the optimum positive pressure phase within the pericardial sac was

FIGURE 2A: Venturi tube (V) with cam (C) disengaged, producing the diastolic phase of the pump cycle. Note the collapsed mantled balloon on the cannula.

FIGURE 2B: Venturi tube with cam engaged producing the systolic phase of the pump cycle. Note distention of the mantled balloon.
120 mm. Hg. at 60-70 cycles/minute. The response to this pressure on the heart chambers in experiments that lasted 10 to 30 minutes gave the following average systolic, diastolic and mean pressures in mm. Hg.: Systemic artery 64/20-39, pulmonary artery 45/9-14 and pulmonary vein 67/7-15 (Figs. 1A, 1B and 1C above Can.)

Pressures were also taken in the thoracic inferior vena cava giving a range of 14/2 - 50/5 as compared with controls that ranged from 5/-2 to 30/15 mm. Hg.

Vasoconstrictors (adrenalin 0.1 per cent or Levophed 8/mil. sol. in 500 cc. D/W 5 per cent) were infused either into a peripheral artery or vein. Infusion into the artery gave a prompt elevation in blood pressure of 10-30 mm. Hg. which was sustained during five to ten minutes. The response following intravenous infusion was often less marked and less sustained, lasting two to five minutes after infusion was discontinued.

Plasma expander (Dextran) was found to increase the blood pressure when it was infused intravenously in massive doses varying from 1000 to 1500 cc. Response of the blood pressure with the use of Dextran was a rise in systemic blood pressure of approximately 10-30 mm. Hg. The

FIGURE 3: Above-down: (a) Bal. II; mantled balloon and cannula. (b) Bal. I, balloon and cannula. (c) suction tube with the rubber flanged cannula in the central lumen. (d) rubber flanged cannula. (e) calibrated hollow ground cutting tube.
use of Dextran intra-arterially showed no effect on the blood pressure. Plasma expander was discontinued in later experiments because it was found that its use contributed to high pressures in the vena cava (90/30 mm. Hg.), often higher than in the femoral artery. This situation was reversed when vasoconstrictors were subsequently infused intravenously. Pumping with the cannula introduced into the right side of the pericardial sac produced higher right ventricle pressures than when the cannula was placed on the left side. Right-side pumpings gave pressures of 140-150/25 in the right ventricle with a mean of 50 mm. Hg. This pressure was higher than the systemic which was 80/40 with a mean of 60 mm. Hg.

Pathology

Microscopic sections of the central and peripheral parts of the lung in these experiments showed: (a) mantle hemorrhages especially in the smaller pulmonary arteries; (b) massive hemorrhage of the lungs; (c) septal lymphangiectasis; (d) marked venous dilatation; (e) bleeding into the alveoli, and (f) intrapleural hemorrhage. It was consistently found that the mantle hemorrhages predominated in those experiments when pumping was done on the right side, whereas venous dilatation and congestion with veno-capillary hemorrhage predominated in lungs when the cannula was introduced on the left side of the pericardial sac. The cause of death in these experiments was attributed to cardio-respiratory insufficiency (anoxia) secondary to a low cardiac output during experimentation and severe damage to the lungs.

The survival rate in the 36 experiments after 10 to 30 minutes in asystole was as follows: two dogs were total survivors; two survived for 48 hours; three for 12 hours and one for four hours.

(B) Mechanical heart compression by intermittent inflation of a balloon placed behind the left ventricle within the pericardial sac (Fig. 3B).
Seven experiments were done in this group. Air pressure was conducted intermittently to a balloon also by the Venturi tube. Optimum pressure in the balloon was found to be 250 mm Hg at 60 cycles/minute. A high pericardiectomy was done at the level of the left auricular appendage and above the left phrenic nerve. The balloons were made from \( \frac{3}{8} \)" Penrose tubing fixed to the end of a hockey stick-shaped cannula. This was introduced through the pericardiectomy and the balloon was placed behind the left ventricle. The pressure was projected directly against the left ventricle while the right ventricle was squeezed between the anterior surface of the pericardium and left ventricle itself (Figs. 6A and 6B).

The experiments lasted 4 to 30 minutes and gave the following average systolic, diastolic and mean pressures in mm. Hg.: Systemic artery 81/30-39, pulmonary artery 47/13-24 and pulmonary vein 50/12-21. (Figs. 1A, 1B and 1C above Bal. 1). Vena cava pressures were not monitored because experience in the previous experiments with the cannula led us to think that the low survival rate and lung damage was caused by an excessive pressure in the pulmonary artery and vein.

Pathology: Macroscopically the lungs appeared normal. Microscopic sections of the lungs of the dogs in these experiments gave no data suggestive of severe damage to the pulmonary vascular tree or alveoli due to pumping.

FIGURE 5: Grass polygraph pressure recorder.
Of this group, four dogs survived more than 12 hours. Two died of empyema a week later and one died the following day of pneumothorax due to a tear of the left lung during catheterization of the pulmonary vessels. One remained a total survivor.

(C) Mechanical heart compression by intermittent inflation of a mantled balloon also placed behind the left ventricle (Figs. 6A, 6B). The balloon used in this series of eight experiments was of similar construction as the one used in the previous experiment (Fig. 3A). Expansion of the balloon was limited by a mantle or pouch of nylon cloth when it was inflated. Thus the balloon acquired a spherical shape with increased tension. Expansion of the balloon toward the auricles was considerably reduced. The optimum pressures in this balloon ranged between 450 and 500 mm. Hg. with the same systolic/diastolic phase as in experiments (A) and (B).

The results obtained by pressure monitoring during the experiments which lasted from 3 to 65 minutes gave the following average systolic, diastolic and mean pressures in mm. Hg.: Systemic artery 80/31-41, pulmonary artery 41/14-25 and pulmonary vein 22/12-15. (Figs. 1A, 1B and 1C above Bal. 2).

Pathology: Macroscopic observations and microscopic sections revealed no damage to the lungs. Of the group, four dogs were total survivors, one died two days later, the remaining three died on the table of technical difficulties.

(D) Manual cardiac compression. The results of the three previous experiments described above were compared with the results of four experiments obtained by manual compression of the heart. Five surgeons participated in these experiments, two or more taking part on each of the four animals. Each surgeon massaged the heart for a period of three to five minutes, usually alternating the right and left hand. The operator was kept unaware of the effect that his cardiac resuscitation had on the pressures monitored.

The graphs of the pressure responses to manual compression of the heart were made by averaging the sum of the pressure curves in the

![Figure 6A](https://example.com/figure6a.png) Mantled balloon in the diastolic phase behind the left ventricle within the pericardial sac. Key to abbreviations: (L.A) left auricle; (L.V) left ventricle; (A.O) aorta; (P.A) pulmonary artery. **FIGURE 6B**: Mantled balloon in systolic phase (inflated) behind the left ventricle within the pericardial sac. Note the selective compression of the left ventricle. Key to abbreviations: (see Fig. 6A).
four experiments independent of the operator massaging. The results obtained gave the following average systolic, diastolic and mean pressures in mm. Hg.: Systemic artery 50/27-35, pulmonary artery 51/12-32 and pulmonary vein 19/6-6. (Figs. 1A, 1B and 1C Man. M.).

Discussion

Pneumomassage or heart massage by inflation of the pericardial sac with consequent compression of all the anatomical structures within the pericardium, was feasible because the pericardium has a high tensile resistance. This membrane withstand pressures of 350-500 mm. Hg. in dogs, and 600-1125 mm. Hg. in human cadavers (Bencini and Parola). The pressure in the pericardial sac was transmitted in inverse proportion to the thickness of the walls against which it compressed. For instance, the vena cava, compressed pulmonary veins and pulmonary artery were most compressible. This sequence was followed by the right ventricle and lastly the left which has the thickest wall. In other words, the anatomical condition is the reverse of that which is needed to maintain a good flow of blood from the venous system through the lungs to the systemic circulation. The following table which represents the percentage relationship between the average femoral artery, pulmonary artery and pulmonary vein mean pressures to the controls, was as follows:

<table>
<thead>
<tr>
<th>Mean Pressures</th>
<th>Surface exposed to pressure</th>
<th>Wall thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral artery</td>
<td>44 per cent</td>
<td>Left Ventricle</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>50 per cent</td>
<td>Right Ventricle</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>250 per cent</td>
<td>Left Atrium</td>
</tr>
</tbody>
</table>

One detail of interest (Figs. 1B, 1C and Can) is that the average pulmonary vein mean pressure is higher than that of the pulmonary artery. This abnormal response was attributed to be the cause of massive hemorrhage of the lungs which was evident macroscopically as a petechial pleural hemorrhage. A cut section of the lungs showed intense congestion and frothy fluid within the bronchi. Microscopic sections showed diffuse hemorrhage of the lungs and mantle hemorrhages.

With the abnormal pressure and pathology of the lungs in mind an hypothesis was contemplated to explain the hemodynamic paradox in the systemic and pulmonary circulation. It was thought that because the left ventricle was compressed less than the right, the cardiac output should be diminished and that with the right ventricle pressure above normal, the blood consequently pooled in the pulmonary vein and left atria. The last two act as a single chamber of thin walls receiving with each compression a back flow towards the lungs which may be responsible for the pulmonary venocapillary hemorrhage. This situation was most evident when pumping was done on the left side. When pumping on the right side, pulmonary artery pressures increased over pulmonary vein pressures; in these cases mantle hemorrhages were most conspicuous. The experience accumulated in these experiments gave ample ground work for technical improvements to be made in mechanical heart compression. Some theoretical considerations were proposed, i.e., (1) the pressure system should be more localized to the ventricles; (2) the left ventricle should be compressed more than the right and (3) the thin-walled structures should be spared.

It was thought that a balloon attached to the end of a cannula could qualify for this purpose if it were placed behind the left ventricle within the pericardial sac. In this way the left ventricle would receive the main impact from the intermittently expanding balloon. The right ventricle would secondarily receive a residual pressure through the interventricular septum, being compressed between the pericardium and the left ventricle (Figs. 6A, and 6B).

With these experiments, the percentage of the average mean pressures of the femoral artery, pulmonary artery and pulmonary vein against controls gave the following data:

<table>
<thead>
<tr>
<th>Mean pressures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral artery</td>
<td>44 per cent</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>120 per cent</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>300 per cent</td>
</tr>
</tbody>
</table>

(systolic 17 mm. Hg. higher than with the cannula
(diastolic 10 mm. Hg. higher than with the cannula)

These figures showed an increase of the pulmonary artery and pulmonary vein pressures when compared with the experiments of pneumomassage. Consulting Figs. 1B and 1C above Bal. 1, it was found that the average pulmonary artery means are higher than those of the pulmonary vein by 3 mm. Hg. This is an improvement although far from adequate. More survivors were obtained in this group and the lungs showed no pathological changes attributable to any acute vascular accident.

The new system of mechanical compression had some obvious defects: (1) the balloon expanded upwards compressing the left atria. This was revealed by the high
pressure response in the pulmonary vein; (2) the balloon expanded towards the pericardiotomy, finally bursting the pericardium; (3) balloons being made of rubber (like all elastic materials), if subjected to intermittent distention, produce heat, distend and then rupture; (4) the average systemic pressure obtained was too low.

In order to localize the pressure more to the left ventricle, a new type of balloon was constructed similar to the previous, except that it was included in a mantle of nylon cloth and was closed like a tobacco pouch around the cannula (Fig. 3A). The percentage relationship between the average femoral artery, pulmonary artery and pulmonary vein mean pressures to the controls was as follows:

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Percentage</th>
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</thead>
<tbody>
<tr>
<td>Femoral artery</td>
<td>48</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>125</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>213</td>
</tr>
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</table>

In these figures two improvements were observed: the femoral artery pressure had increased considerably and the pulmonary vein pressure was now only double that of the controls. The pulmonary artery pressure was 10 mm. Hg. higher than that of the pulmonary vein against controls which show a difference of 14 mm. Hg.

The results of the three experiments, pneumomassage and pumping with the two types of balloon, were then compared with those pressure responses obtained by manual compression. The average mean of these pressures is represented as a percentage of the control means as follows:

<table>
<thead>
<tr>
<th>Pressure</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral artery</td>
<td>40</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>160</td>
</tr>
<tr>
<td>Pulmonary vein</td>
<td>86</td>
</tr>
</tbody>
</table>

No important conclusion can be obtained from manual massage because the human factor enters predominantly into the problem. Fatigue comes within approximately three minutes when massaging rapidly at 100–120 compressions per minute. Massage at 70/minute could be maintained for 10 minutes with one hand. Whether the hand was in fatigue or not, the results are variable; slight displacement of the fingers from one area to another of the heart changes the pressure response in the pulmonary artery and systemic artery. Nonetheless, some interesting data have been collected, i.e., (1) none of the participants produced any marked increase in pulmonary vein pressures which indicated that the operators were aware that the ventricles should be the chambers to be selectively compressed; (2) pulmonary artery means were high because compression was more effective over the thin walls of the right ventricle; (3) pressures began to drop off with fatigue; (4) better systemic pressures were obtained when the operators used their strongest hand. When the heart was compressed so that the thumb encircled the left ventricle and the fingers the right ventricle and when the participant massaged at a rate of 60–70 compressions per minute; pressures decreased as frequency increased above this rate. The average pulmonary artery pressure means were 12 mm. Hg. above controls due to the excessive pressure of the fingers compressing the thin wall of the right ventricle. A low average femoral artery mean was obtained and varied continuously by as much as 60 mm. Hg. due to fatigue and inadequate technique.

If the heart is squeezed so that the thumb, which is the strongest finger, presses against the left ventricle, providing that it does not compress too near the conus, a better systemic pressure is obtained with little risk of the thumb rupturing the myocardium. 3,4,6

Hand massage has the following advantages over mechanical heart compression: (1) no instruments other than a knife are essentially required. Respiration can be done mouth to mouth until the thorax is closed; (2) due to its "simplicity" it is the least time-consuming intervention. This factor is the most important of all as the survival rate drops considerably when massage is started after four minutes; 3,4 (3) a satisfactory pressure response in both the pulmonary and systemic circulation is better obtained if experienced hands are massaging.

Mechanical heart compression of the heart had the following advantages over manual massage: (1) pressures in the femoral artery were constant; (2) massage with an adequate balloon would be useful when the heart needed a prolonged period of compression for resuscitation; (3) it has proven to be much less traumatic to the heart with no risk of myocardial rupture. Mechanical heart compression may prove to be of some use in surgery in those cases when the heart's condition is unstable after heart resuscitation. The balloon in this case could be placed behind the left ventricle under the pericardial sac with the pressure tube brought through a stab wound in the thoracic wall. In this way resuscitation would be possible without having to reopen the thorax. Likewise, during an abdominal intervention the balloon could be placed in the pericardial sac behind the left ventricle via a transdiaphragmatic approach with the tubing coming out through a wound in the midline of the epigastrium. We do not see any future in mechanical
heart compression outside of the surgery or emergency room. At the present time an attempt has been made to secure a more satisfactory balloon which is being made commercially for the purpose of future experimentation.

SUMMARY

General considerations concerning a realistic approach to heart resuscitation have been discussed.

Three methods of mechanical heart compression have been described, and the results obtained were compared with those of hand massage and controls.

Some opinions based on the experimental data obtained, as to the characteristics of the reciprocal advantages with manual heart massage, have been evaluated.

ventricles of the heart, have been presented.

The possible application of mechanical heart compression, after due consideration of the reciprocal advantages with manual heart massage, has been evaluated.

ACKNOWLEDGEMENTS: We wish to express our appreciation to Mr. E. F. Andrews for his part in initiating this project and developing the instruments for its study. We also wish to thank Eleanor Humphreys, M.D. for her kind advice and study of the pathology of this project. We express our gratitude to Mr. W. Rank and Mr. H. Dotson for technical advice and assistance.

RESUMEN

Se diserta en general, sobre los métodos realistas para la resucitación cardiaca.

Se describen tres métodos de compresión cardiaca mecánica y los resultados obtenidos se han comparado con los de el masaje manual y con los controles.

Se presentan las opiniones que se basan en los datos experimentales logrados con respecto a las características de un balón que puede considerarse ideal para la compresión selectiva de los ventriculos.

La aplicación posible de la compresión mecánica del corazón se valúa después de la consideración de las ventajas recíprocas con el masaje manual.

RESUMÉ

Les auteurs exposent les considérations générales au sujet d'une tentative vraiment pratique de résurrection cardiaca.

Trois méthodes de compression cardiaca mécanique ont été décrites et les résultats obtenus furent comparés à ceux des massages manuels et des témoins.

Les auteurs émettent quelques opinions sur les données expérimentales obtenues, comme sur les caractéristiques d'un ballon qui peut être considéré comme technique- ment idéal pour une compression sélective des ventricules.

L'application possible de la compression cardiaca mécanique a été évaluée après estimation sérieuse des avantages comparés du massage cardiaca manuel.

ZUSAMMENFASSUNG

Diskussion allgemeiner Gesichtspunkte hinsichtlich eines wirklichkeitsnahen Weges zur Bekämpfung des Herzstillstandes.

Beschreibung von drei mechanischen Methoden der Herzkompression; die erzielten Ergebnisse wurden verglichen mit der manuellen Massage und Kontrolle. Darstellung gewisser Angaben, die sich auf die gewonnenen Untersuchungsergebnisse stützen hinsichtlich der Eigenschaften eines Ballons, den man als technisch ideal für eine selektive Kompression der Herzkammern ansehen kann.

Auswertung der möglichen Anwendung der mechanischen Herzkompression nach gebührender Erwägung der restriktiven Vorteile der manuellen Herzmassage.

REFERENCES