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SURGICAL CLOSURE OF DEFECTS OF THE INTERAURICULAR SEPTUM BY USE OF AN ATRIAL WELL*

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BOSTON

DEFECTS of the interauricular septum in the human being carry a variable prognosis. Small openings are known to be tolerated rather well through a long span of life. Large defects give left-to-right shunts that enormously increase the flow of blood through the right side of the heart and the pulmonary circuit, thereby leading to right-sided heart failure in early or middle ages. The gravity of the problem makes it quite worth while to develop methods whereby defects of moderate or large size can be closed surgically. This communication summarizes certain of our investigations, which were made in the effort to reach this goal.

Various methods have been suggested or have actually been used in the attempts to close atrial septal defects. Those [1, 2] who have been developing extracorporeal pump-oxygenators hope to divert blood from the heart long enough to permit opening of the organ and closing of a hole in the septum under direct vision. Efforts have been made to use such an apparatus to permit closure of a septal defect in man[1] but as yet no successes have been reported. Murray[3] has passed mattress sutures of silk or strips of fascia through the heart, attempting to place these in the plane of the septum. These can partially block a septal opening, and if the mattress stitches are drawn close together the anterior and posterior walls of the auricles can be brought closer to one another, thereby partially reducing the size of the hole in the septum. The method can hardly be expected to give complete closure of a septal opening. Swan et al.[4] have inverted the right and left auricular appendages to the septum so that a septal opening can be plugged by holding the inverted appendages in this coapted position with mattress stitches passed through them. Such inversion was apt to block pulmonary veins, and the method has been abandoned. Cohn[5] suggested pushing in the right auricular wall to plug a septal opening, suturing the inverted wall to the septum (around the periphery of the defect). No report of the successful use of this method has been published. Bailey[6] has employed a modification of Cohn's technic, by inserting a finger through the auricular appendage into the auricle so that the digit can guide the placement of the sutures used for drawing and attaching the lateral auricular wall to the septum at the periphery of the defect, thereby plugging the hole. This method might be of great value for the treatment of an opening that lies in the middle portion of the septum, but it is impractical for treatment of the vast majority of defects since they lie high, low or forward in the septum. To close such openings by inversion of the auricular wall would almost certainly obstruct the orifice of the superior vena cava, the inferior vena cava or the tricuspid valve. Hufnagel and Gillespie[7] have devised pairs of flat, plastic buttons, which can be screwed together, one disk to be placed on the left side of the septum while the other rests on the right of the septum, covering any hole in it. These buttons, put into place by a simple and ingenious handle, have been found to be effective in closing septal defects created in dogs. They will probably be of little value for human patients, in whom the septal defects seldom have a rim around the entire periphery; it is essential to have a complete rim to hold the double button in place.

Each of the methods enumerated above for closing a defect of an auricular septum has serious technical disadvantages, and we do not believe any of them will have more than a limited usefulness. Pursuing a somewhat different line of thought, we considered it possible to attach temporarily some sort of cone-shaped rubber bag (open at the top) to the right auricular wall so that the auricle could be opened and blood allowed to rise up into the rubber "well." Through this column of blood, it might be possible to pass the operator's fingers down into the auricle, to find the septal opening, and to

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close it either by direct suture or by the onlay of a piece of flat substance (such as a plaque of fascia, pericardium or plastic). Investigations were made in the Laboratory for Surgical Research at the Children's Hospital to determine, first, how it might be possible to attach such an appliance to an auricle and, secondly, how the heart might stand opening of its auricle to atmospheric pressure. This report is a summary of our findings.

Laboratory Studies

With mongrel dogs, ranging in weight from 17 to 26 kg., a study was made of various methods that would allow temporary attachment of a conical

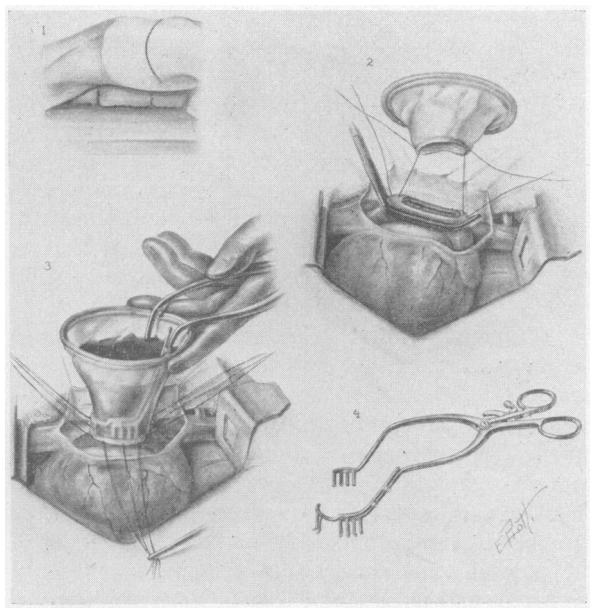

Figure 1. *Application of a Rubber Well to the Right Auricle. 1 = Position of animal for exposure of the right side of the heart. 2 = Pericardium opened, with a special clamp placed across the base of the atrium and the atrial wall slit open beyond this clamp; the rubber well is being sewed to the edges of the auricle with silk sutures. 3 = Position of silk sutures around the base of the well (the atrial clamp has been removed, and blood has been allowed to rise up into the well). 4 = Type of self-retaining retractor that is inserted into the well to spread open the orifice of the auricular wall.*

piece of pliable cellophane or rubber to an auricular wall in such a way that the seal would not leak blood and also in such a way that the auricular wall would not be left damaged after removal of the well. At first, it seemed that it might be possible to glue a "well" to the auricular wall with rubber cement, plastic cement or other adhesive substance, but all these were found to be unreliable. Later, it was determined that a well and the auricular wall could be held together satisfactorily with interrupted sutures of No. 0000 Deknatel silk. The completion of the union required no more than ten or fifteen minutes, and the junction could be made watertight.

After determining that it was feasible to attach some sort of bag or well to an auricle in a reliable way, we turned our attention to the careful designing of a rubber well that might best serve the purposes for which it was intended. After several different models had been constructed and tried a type that fulfilled all the requirements was arrived at (Fig. 1). It is a truncated cone, open at the top and bottom, the wall being made of pliable, but extremely tough, rubber 0.38 mm. in thickness. The lower rim, through which the anchoring silk stitches are passed, is reinforced by a double thickness of such rubber. The upper edge of the well incorporates a coiled spring, which expands and keeps open the mouth of the well. A well 10 cm. high was found to be adequate to contain the column of blood that rose in it when a dog's auricle was opened; the column seldom went above 5 or 6 cm.

After a well had been attached to an auricle, it was found desirable to have some sort of self-retaining retractor that could be inserted into the well and placed in such a way that the opening in the lateral wall of the auricle (and the attached ring of rubber) could be stretched open to make an orifice 3 or 4 cm. in diameter. After experiments with different forms of retractors, the instrument shown in Figure 1 was adopted.

A series of 114 dogs were used to develop proficiency in the technics of applying a well to an auricle. When a well was open and received blood from the auricle, clotting was prevented by the addition every few minutes of a few cubic centimeters of heparin solution; in no instance was there clotting in the well. During the time such wells were open to atmospheric pressure, observations were made on the cardiac action, and direct pressure readings were made with electrical manometers from the right auricle, the right ventricle and the carotid artery. Dogs, with the wells attached, were maintained under pentobarbital sodium (Nembutal) anesthesia, with positive-pressure ventilation of the lungs through an endotracheal tube. Detailed listing of these physiologic studies will be made elsewhere; general statements and conclusions regarding them are as follows:

Temporary clamping of an auricle, and placement of stitches in the auricular wall and septum, did not produce any disturbing irregularities of the heart; seldom were there more than a few dropped beats or extrasystoles.

The pulse rate rarely changed to any important degree.

The level to which blood rose in the well varied from 4 to 8 cm. above the lateral surface of the right auricle. This level varied a centimeter or two with the respiratory excursions.

At no time was air sucked down into an auricle.

The peripheral blood pressure was always at an adequate level.

The well could be left open for periods up to one hour (the longest period studied), and during such times the circulation could be maintained in a stable manner.

With an open well, one or several fingers could be passed down through the pool of blood so that the right auricle could be entered and its interior slowly and carefully explored by digital examination. It soon became evident that one could become quite proficient in recognizing the various landmarks such as the tricuspid valve, the coronary sinus, the eustachian valve, the orifices of both venae cavae and the various parts of the interauricular septum. Pieces of septum 1 to 3 cm. in diameter were then cut out so that the defects thus created could be closed by various methods and studies could be conducted of the comparative values of the several methods of septal closure. After these interauricular manipulations had been completed, the rubber well was removed, and the lateral wall of the auricle was closed with interrupted figure-of-eight stitches of silk.

Six general methods of closing interatrial septal defects were investigated. Detailed analysis of these will be published elsewhere, but the general features were so clear that they can be summarized briefly here.

Free grafts of pericardium could be sewed to the septum to cover over a defect, the graft being sutured to the septum with an appropriate number of interrupted silk sutures. These grafts were tolerated quite well, became incorporated into the substance of the septum and subsequently became smoothly covered by endothelium. Clotting on them was never a problem. The greatest drawback to the method was the fact that the patch of thin and soft pericardium was sometimes difficult to feel with the palpating finger in the auricle, thus complicating placement of the graft. Furthermore, the graft material, being soft and pliable, required a large number of sutures at its periphery to give complete septal closure.

Pieces of vein were turned inside out and used for free grafts to cover over septal defects. They had the same disadvantage noted for the pericardial grafts, and in addition they were inadequate when large openings had to be closed.

The tip of the right auricular appendage could be cut off and used as a patch to sew to the septum and thus to cover over the septal opening. This left an irregular wad of tissue attached to the septum, which, however, exhibited an amazing tendency to flatten down, become incorporated into the septum and smoothed over during the ensuing six to eight weeks. On the whole, the method was quite satisfactory, but it had the disadvantages of requiring the steps of amputating the auricular appendage to obtain the material to be used for the grafting.

Defects were closed by the use of Hufnagel prostheses, which consist of two button-like disks that can be screwed together by virtue of a threaded central stem that one of them carries. One of these plastic buttons could be placed on the left side of the septum, and the other on the right side. Provided there was a rim of tissue around the entire periphery of the septal opening, these buttons could be put in position within a few moments, completely blocking the opening, and were covered over by endothelium in a most astounding manner in a few weeks.

Defects were closed by the application over them of a sheet of plastic material, 0.5 to 1 mm. in thickness, cut to appropriate size and shape, which was sewed to the septum with interrupted silk sutures. Nylon and polyethylene were very good to work with. A piece could easily be cut out with scissors at the operating table; it could be pierced without difficulty by needles. The material had enough body and stiffness so that it could be readily felt with the palpating finger in the auricle. The material was tolerated extremely well, was seldom accompanied by any serious clotting and was covered over by endothelium quite rapidly, making a smooth interior for both auricles.

Some defects were closed by the use of interrupted silk sutures, the edges of the septum being grasped so that they could be drawn together. This method was not suitable for closure of large openings, because great tension on sutures made them tear out of the septum. For openings less than 1.0 cm. in maximum dimensions, such a closure by direct stitching was extremely satisfactory; the silks became incorporated within the septum and were covered over by a smooth endothelium, free of surface clot.

In summary, our various observations convinced us that septal defects that have margins of tissue around their entire periphery can be quickly and effectively closed by the use of Hufnagel buttons, that septal defects of almost any size, shape or position can be covered over effectively by the insertion and anchoring into place of a sheet of plastic material, and that defects smaller than 1.0 cm. can generally be closed by direct suture and approximation of the septal edges.

Clinical Application

After extensive trials with the use of auricular "wells" in experiments on animals, it was considered justifiable to attempt closure of defects of the interauricular septum in man. To date, 6 patients have been operated upon. For work on human beings, a rubber well has been constructed with a height of 15 cm., an upper-orifice diameter of 13 cm. and a lower-orifice diameter of 4 cm. For use with this, a larger self-retaining retractor has

been devised, its blades being of sufficient length to dip down into such a deep well. When the jaws are opened, the orifice in the lateral wall of the auricle (and in the base of the well) can be expanded to 6 cm. or more in diameter. A deep well was provided to take care of any excessively high column of blood that might be encountered in human patients. In the limited experience to date, it has not been necessary to use the entire height of the rubber bag at any time; the bag has generally been folded or rolled down upon itself so that only a third or a half of its height has been employed, thereby simplifying holding of the bag and working through it.

Six patients varying from four to sixteen years of age have been operated upon. The left-right flows of blood through these shunts were shown by preoperative catheterization to range from 6.7 to 22.3 liters per minute. Four of the children had been known to have some degree of right-sided heart failure and had been treated by digitalization, low-salt diet and other supportive measures.

In no case was there the slightest difficulty in attaching the rubber well to the enlarged right auricle. To sew the rubber appliance to the auricle required fifteen to a maximum of twenty minutes. In no operation was there leakage at the suture line. There has been no clotting within the well, the blood being kept fluid by regional heparinization. Examination of the peripheral blood after operation showed that the clotting time had returned to normal in each subject within four hours.

In the first case, the well was kept open for twelve minutes. This was tolerated very well, in spite of the fact that the child had been in heart failure prior to operation. With increasing experience with the operation on human beings, it became evident that there was little need for haste in closing the well. In 1 case, the well was open for two hours and five minutes. Therefore, one could be careful and deliberate about the intracardiac manipulations and repair.

Three methods of attempting septal closure have been employed. In the first 3 patients, defects varying from 2.5 to 5 cm. in maximum dimensions were found. Each had a rim of septum around approximately half the opening, the remainder of the orifice having no rim of tissue that could be grasped. Rather unwisely, double buttons of the Hufnagel type were put into place, in the hope that the grasping of a rim halfway around the button would anchor it securely enough to hold the appliance in place. Although it was realized that under such circumstances a button would not completely occlude the septal window, it was hoped that a baffle would be created that would greatly reduce the flow of blood through the shunt. All 3 of these cases ended disastrously, death occurring within a few days; in each, the button worked loose. In 2 cases it fell freely into the right or left auricle, and in the third it retained part of its septal attachment but turned over and partially obstructed the tricuspid valve. These bitter experiences make it quite evident that such buttons (held in place by merely screwing two of them together), although highly satisfactory in the animal experiment, in which there is a margin of tissue around the entire rim of the septal defect, are rarely safe in human beings, who are too likely to have incomplete rims around the opening and hence do not have sufficient substance to hold buttons in place securely.

In a fourth patient a large and high septal defect was found, measuring 4 cm. in diameter. This had a good rim of septum inferiorly but none superiorly. A sheet of polyethylene, 0.5 mm. thick, was used to cover the opening. It was cut into an oval 4.5 cm. wide and 5.0 cm. long, was securely anchored to the septal wall above and posteriorly, and was sutured to the septum inferiorly. Unfortunately, after the plastic was in place, it was found that it was too long; it covered the septal defect quite well but projected down unnecessarily over the annulus of the tricuspid valve. In spite of this obvious error it was decided to leave it, rather than to attempt replacing it with a smaller plaque. This patient was in reasonably satisfactory condition for three days and then suddenly died. At autopsy the septal defect was found to be completely closed off, but the excess plastic inferiorly was found to be underlain with clot, which had extended downward, partially obstructing the orifice of the tricuspid valve. The plastic plate had been too large and had not been anchored down sufficiently along its caudal border.

In the fifth case (Fig. 2), the septal opening was found to be 2 cm. wide and 3 cm. long. It was quite high. There was a good rim of septal tissue inferiorly and anteriorly, but none superiorly and posteriorly. A piece of nylon, 0.8 mm. thick, 2.5 cm. wide and 3.5 cm. long, was put in place to cover the septal defect. This was anchored inferiorly and anteriorly by interrupted stitches to the available rim of septum. Above and behind, the silk sutures grasping the edges of the nylon plate were run out through the auricular wall; as these sutures were drawn up and anchored externally, the plate could be snugly drawn up against the inner surfaces of the atrial wall. This patient, who was discharged from the hospital on the thirteenth day, is in excellent condition two months after operation and the cardiac murmur has disappeared. Postoperative catheter studies have not yet been performed.

In the sixth patient (Fig. 3), two septal openings were found. A centrally located one was 1.5 cm. long and 1 cm. wide. It was closed with interrupted sutures of silk. The second defect was larger and was situated posteriorly and inferiorly; it was 3.5 cm. long and a little more than 1 cm. wide. There was a good rim of septal tissue along the anterior and superior borders of the defect, but none below or behind. A series of mattress stitches were placed,

the available anterior margin of the opening being grasped, and the stitches being passed out through the posterior wall of the auricle and brought to the right of the right pulmonary veins. When these sutures were drawn snug and tied outside of the auricle, the septal edge was drawn posteriorly, and simultaneously the posterior wall of the auricle was drawn in forward. Both these movements combined

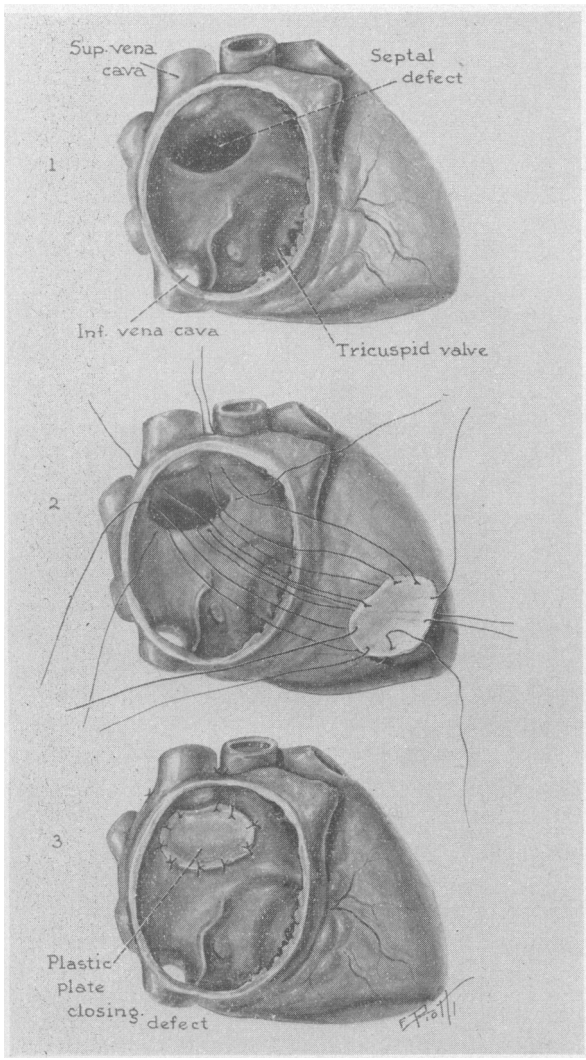

FIGURE 2. *Type of Repair Employed in Case 5.* 1 = *A very high septal defect, with a good rim of septal tissue inferiorly and anteriorly (no rim of septum above and posteriorly).* 2 = *Sheet of nylon of appropriate size and shape to cover the septal defect (silk sutures have been threaded through the rim of the septal defect inferiorly and anteriorly; superiorly and posteriorly silk sutures from the nylon sheet have been run out through the auricular wall.).* 3 = *Nylon sheet anchored in place by these various silk stitches.*

to close off the septal opening effectively and also to divert all blood from the right pulmonary veins into the left auricle. This patient made a rapid recovery, was discharged from the hospital in twelve days and was in excellent general condition two months later; the precordial murmur has disappeared.

From the observation on human beings to date, it seems clear that a rubber auricular well can be

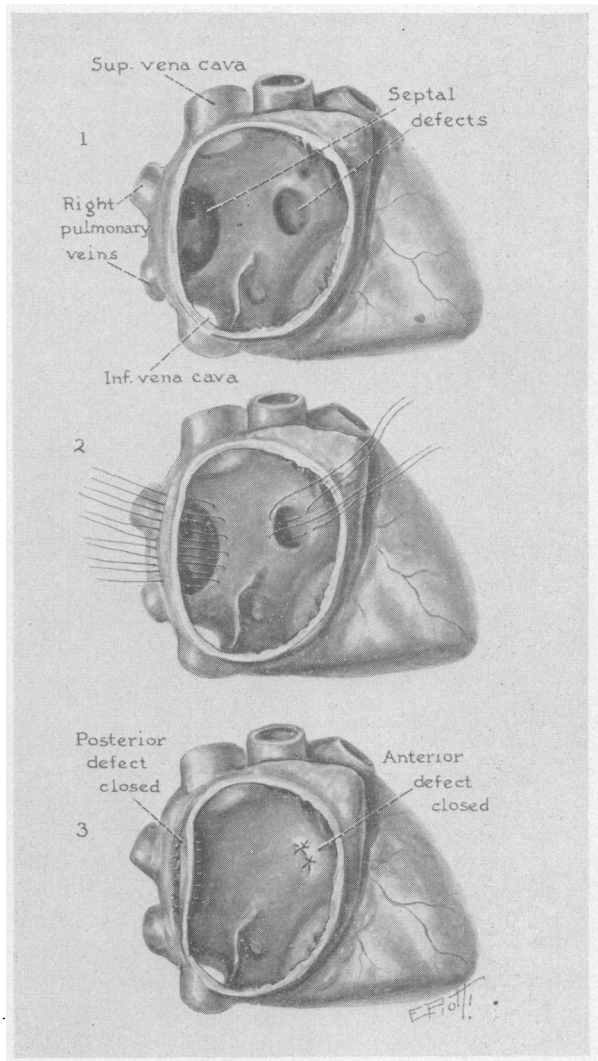

FIGURE 3. *Findings and Type of Surgical Therapy in Case 6.* 1 = *Two interauricular defects found. (The small anterior one had a good margin of tissue around its entire periphery; the posterior defect had a good rim of septum along its anterior margin, and no rim of tissue posteriorly.)* 2 = *Method of placing sutures for closure of the two defects. (The smaller, anterior opening is to be closed by approximation of its edges with interrupted silk stitches, and the larger, posterior defect treated by insertion of interrupted silk mattress stitches, grasping the margin of the septum and then running these stitches out through the posterior wall of the auricle, to the right of the pulmonary veins.)* 3 = *Sutures drawn tight to close both septal openings.*

attached to the human heart, that the heart can be opened into the base of such an appliance for a considerable time, and that the auricle can be entered through such a well to permit a defect of the interauricular septum to be closed. It is apparent that screw-on plastic buttons of the Hufnagel type will probably have only limited usefulness in human

patients because there is often an incomplete rim of septal tissue for the buttons to grasp. A plate of plastic material can be sewed and anchored into place to cover a septal defect, but it must not be made too large for fear of projecting into and giving obstruction of the orifice of a vena cava, the tricuspid valve or the coronary sinus. Without doubt, large septal defects can be suitably closed by application of a plastic sheet if the material is accurately cut and shaped and is carefully sutured into place. Smaller defects can be closed by direct suture and approximation of the septal edges.

Summary

On the basis of extensive laboratory investigations, a method has been developed whereby it is possible to attach an open rubber bag or well to an auricular wall, so that the auricle can be opened into the bottom of this attached sac. Blood rises up into such a well to a height equal to the intra-auricular pressure. Through the pool of blood, kept fluid by heparin, it is possible to enter the interior of the auricle, to locate accurately any septal defect and to close it in a careful manner. A large septal opening can be covered with an onlay sheet of plastic material, held in place by sutures. A small opening can be repaired by direct stitching and approximation of the septal margins.

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THE EVALUATION OF PILOT CLINICS*

The Mass Screening or Health-Protection Program

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BOSTON

IN 1948 and 1949 the Massachusetts Medical Society became interested in the development of multiple screening. After a series of meetings of several committees the Committee on Public Health recommended the establishment of a research screening program.

The Council of the Society, at its annual session in Worcester on May 23, 1949, voted to adopt the following motion: "It is the opinion of the Committee (Public Health) that not more than five pilot clinics should be held in pivotal localities throughout the State to offer, on a voluntary basis, health examinations under the auspices of district medical societies in co-operation with the community hospital and other interested groups."

A subcommittee on pilot clinics was appointed by the President and met on many occasions during 1949, at which time the committee passed on all the policies of the pilot clinic — determining what tests were to be used, how they were to be evaluated against the history and physical examination, and the contents of the letters that would be sent to the persons screened and to the doctors. More recent action of the Council has modified the composition of the Committee and made it advisory in function.

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Objectives of Multiple Screening

In brief, the modern concept of multiple screening consists of the application of laboratory tests by technicians to apparently well persons. The purposes are as follows: to refer persons with suspicious screening results to their family physicians for maximum benefit from early diagnosis and treatment; to find unrecognized or unsuspected early cases of progressive diseases for which testing procedures are administered: to induce people to develop a consciousness of the value of good health and to seek health supervision and early medical care; to influence physicians to practice health supervision and preventive medicine; to prevent disability and premature death from the development and progress of chronic illness; and to prevent economic loss to the individual and community from unemployment, prolonged medical care and welfare costs.

The ultimate objective of multiple screening is the motivation of people with suspicious results found in screening tests toward seeking early medical care; the incidental aim is to find unrecognized cases of progressive illness and also to obtain early treatment of these conditions in the physician's office. An indictment of multiple screening as a mass diagnostic procedure of little value is fallacious, since it is based on false premises.