mination, and science-data analysis and command requirements. Through his support personnel and his direct contact with the DSIF stations, the operations director maintains close control over the spacecraft in order to take action as required, in either standard or nonstandard sequences.

Summary and Conclusions

The path is a long one between the conception of a scientific instrument for space exploration and the goal of obtaining scientific measurements from space, from the moon, or from the atmosphere or the surface of a planet. These instruments must be designed to meet the scientific objectives under adverse environmental conditions and within the constraints of a complex spacecraft system. The limitations of weight, power, telemetry, integration, and reliability must be assessed and appropriately dealt with in the design, development, fabrication, testing, and calibration of the instrument. The instrument must operate satisfactorily in a vacuum-thermal environment for long periods after having been subjected to extreme shock and vibration during the launch and injection sequences.

To successfully fly a scientific instrument in space is an achievement involving a considerable number of man-years and dollars. Such an effort and expenditure of funds must be properly compensated through the attainment of scientific information. If billions of dollars are to be expended on the exploration of interplanetary space and of the moon and the planets, every possible effort must be made by the scientists and engineers in NASA, in universities, and in industry to see that this money is profitably spent.

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Institute for Experimental Surgical Instruments in Moscow

Doctors and engineers in a unique cooperative effort have developed a group of surgical stapling devices.

Timothy Takaro

Under the U.S.-U.S.S.R. exchange agreement, an arrangement was made recently for me to study the structure and function of the Scientific Research Institute for Experimental Surgical Apparatus and Instruments, in Moscow. I first spent 2 months at the institute itself (1 April to 30 June 1962), where I carried out a short experimental project. During the third month I visited nine hospitals, in Moscow, Leningrad, and Kiev, to try to assess the clinical usefulness of the specialized instruments which the institute has developed and for which it is well known. A working knowledge of the Russian language, which I had acquired in previous study in the United States, was invaluable.

The Soviet tradition of close collaboration between surgeons and the designers and makers of instruments is said to stem from the days of Peter the Great, who established a large instrument plant in St. Petersburg. Such names as Pirogoff, Elansky, and Kuprianov are associated with this plant, the oldest and largest of its kind in the Soviet Union. After the Revolution of 1917 it was renamed Krasnogvardets or Red Guard, and, as such, it has continued to function up to the present time.

The Institute in Moscow was founded in 1951, shortly after publication of a report by Gudov, a Russian engineer, describing the first Soviet vascular suturing device (*1*). This instrument, together with other stapling instruments which were developed in subsequent years for a wide variety of uses, have been the institute's principal claims to fame outside the Soviet Union. A great deal of experimental work on the use of these devices has been reported, and a few of the instruments have been used extensively in clinical practice.

More recently, the institute's attention has been focused also on such problems as extracorporeal circulation, with pulsatile flow; hemodialysis; the preservation and transplantation of tissues and organs; and electronarcosis and related fields. A study of synthetic polymers as prostheses to replace blood vessels, joints, cardiac valves, trachea, esophagus, ureters, and bile ducts is also under way. I did not observe any revolutionary advances in any of these fields.

Facilities

The institute is housed in a rather inconspicuous five-story brick building on the northern edge of Moscow. (There are subsidiary branches in Kazan and in Vorsma.) Under one roof are housed a large machine shop; a library; offices for engineers, designers, physicians, and surgeons; and complete laboratory facilities for biological experimentation. In an adjacent building, one of the Moscow city hospitals serves as a clinical base for the institute.

Approximately 350 people are em-

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ployed in this research effort, of whom a third are engineers and a third are medical or ancillary personnel. There are 30 doctors of medicine or biology. In spite of grossly inadequate space and facilities, excellent cooperation and cordial relations were always maintained, and every courtesy was extended to me by all of the institute's personnel.

Organization

The organizational structure of the institute may be best understood by reference to Fig. 1. Of the six major subdivisions, the first, called the Scientific Council, is charged with planning, regulation, and control. This group of approximately 50 engineers and surgeons (20 recruited from outside the institute) decides what major projects to undertake and monitors the work of the institute. It receives reports and delegates specific questions to specialized "Problematic or Thematic Commissions." New ideas for projects, which are first screened by the director, are received from four major sources. These are, (i) the *Information Bulletin*, published by the Information Group of the institute, which scans and condenses quantities of foreign medical literature, translating into Russian whatever seems promising, for circulation among the professional staff; (ii) questionnaires sent by the institute annually to all Soviet surgeons, concerning their needs in instrumentation; (iii) individual proposals from various sources (inventors and experts of various kinds); and (iv) proposals from the personnel of the institute itself. The council recommends the construction of pilot models of instruments or apparatus and, after successful laboratory and clinical tests, may recommend to the Technological Committee of the Ministry of Health that an instrument be mass-produced by the medical instruments industry. Of some 650 instruments tested during the 10 years of the institute's life, 610 are said to have been mass-produced—some only for limited periods.

The second subdivision, under the vice-director for scientific technology, is concerned with technological advice. Again, specialty groups consider specialized questions. In addition, laboratories of metallurgy, chemistry, and electrical engineering are available for conducting tests or making designs or measurements. This group answers questions concerning the construction of devices.

The third subdivision—and, in terms of number of employees, the largest—is the machine shop. There are apparently four machine shops for making experimental models of apparatus and instruments under the jurisdiction of the institute's director. Only one of the shops, however, is located in the institute's main building. The three others are apparently located elsewhere in Moscow and employ an additional 300 workers.

The fourth subdivision, called the Scientific Organization Department, is concerned with more detailed planning (budget, staff, and projects) and with information and translation services, which include publication of the *Information Bulletin* and, since 1957, of an annual volume of collected articles, by members of the institute's staff and others, entitled *New Surgical Apparatus and Instruments and Experience with Their Use* (2). The library, consisting of both medical and nonmedical journals and books, also comes under this department. A number of American journals were represented.

The fifth subdivision (the "Administration of Economics Section") is concerned with personnel, buildings and grounds, and accounting.

The Medical Department, to which I was assigned, is charged with testing new devices in the animal laboratory and in the adjoining city hospital, and with publicizing the results. To this end there are provided laboratories for gross and microscopic anatomy, biochemistry, hematology, and physiology; two operating rooms for experimental surgery on animals; a small vivarium; and a postoperative recovery room. There are offices with little more than desk space for the physicians, surgeons, biologists, physiologists, pathologists, and radiologists engaged in the institute's projects. The "clinical base" of the institute is largely in the adjoining city hospital (No. 40) but extends to many other hospitals as well. I was told that we would visit these later, and we did so. All of the institute's surgeons were assigned to clinical duties on approximately a half-time basis at the adjoining hospital, yet, curiously, I was denied the opportunity to observe their work in this hospital, in spite of my repeated requests to be permitted to do so. Thus, I can describe neither the facilities of the hospital nor the operative work of its staff.

The annual budget of the institute is said to be 1 million rubles (approximately $1,100,000).

Clinical Appraisal of the Instruments

During the 10 years of the institute's existence, 25 different models of suturing devices for a variety of purposes have been developed and introduced into clinical practice (*3*). These devices (see Fig. 2) include (i) instruments to anastomose blood vessels (either end-to-end or end-to-side), nerves (end-to-end), the small and large intestines, and the esophagus; (ii) instruments for placing one or two rows of metal staples across the bronchus, the lung parenchyma, or the vascular elements of the lung hilus, the patent ductus arteriosus, the base of the auricular appendage, the gastric or duodenal stump, the dura mater, the bladder, the cornea, or other tissues; and (iii) instruments for joining together ribs or sternum. Most of these instruments were displayed in the institute's permanent exhibition. For a clinical appraisal of the usefulness of these devices, I felt it important to seek additional sources of information. Therefore, I queried surgeons in nine different surgical clinics, in Moscow, Leningrad, and Kiev, about their views.

The instruments of the thoracic and cardiovascular group that are most widely accepted in clinical practice are those which suture the bronchial stump, or the lung parenchyma, or both. Of the surgeons interviewed, only Ossipov and his group in the Central Institute for Post Graduate Study, in Moscow, did not use these instruments at all. Opinion is divided about which type of stapler is better. Most surgeons were using the bronchus stapler (Fig. 3, left), reported also by Ravitch and Brown in this country (*4*). However, Amosov, chief surgeon of the Institute for Tuberculosis and Thoracic Surgery in Kiev, reports over 1000 cases of pulmonary resections in which only the lung-suturing instrument was used. With this instrument, two parallel rows of staples, staggered with respect to each other, are placed across the long axis of the bronchus (*5*). The individual staples are at right angles to the long axis of the bronchus, instead of parallel to it, as in the earlier bronchial stapler (Fig. 3, top right.) Amosov's technique of pneumonectomy or lobectomy involves separate high closure of the bronchus with the shorter lung-stapling device and transection of the bronchus distal to the clamp. The remainder of the pulmonary hilus is then fitted between the jaws of the larger lung stapler, and another

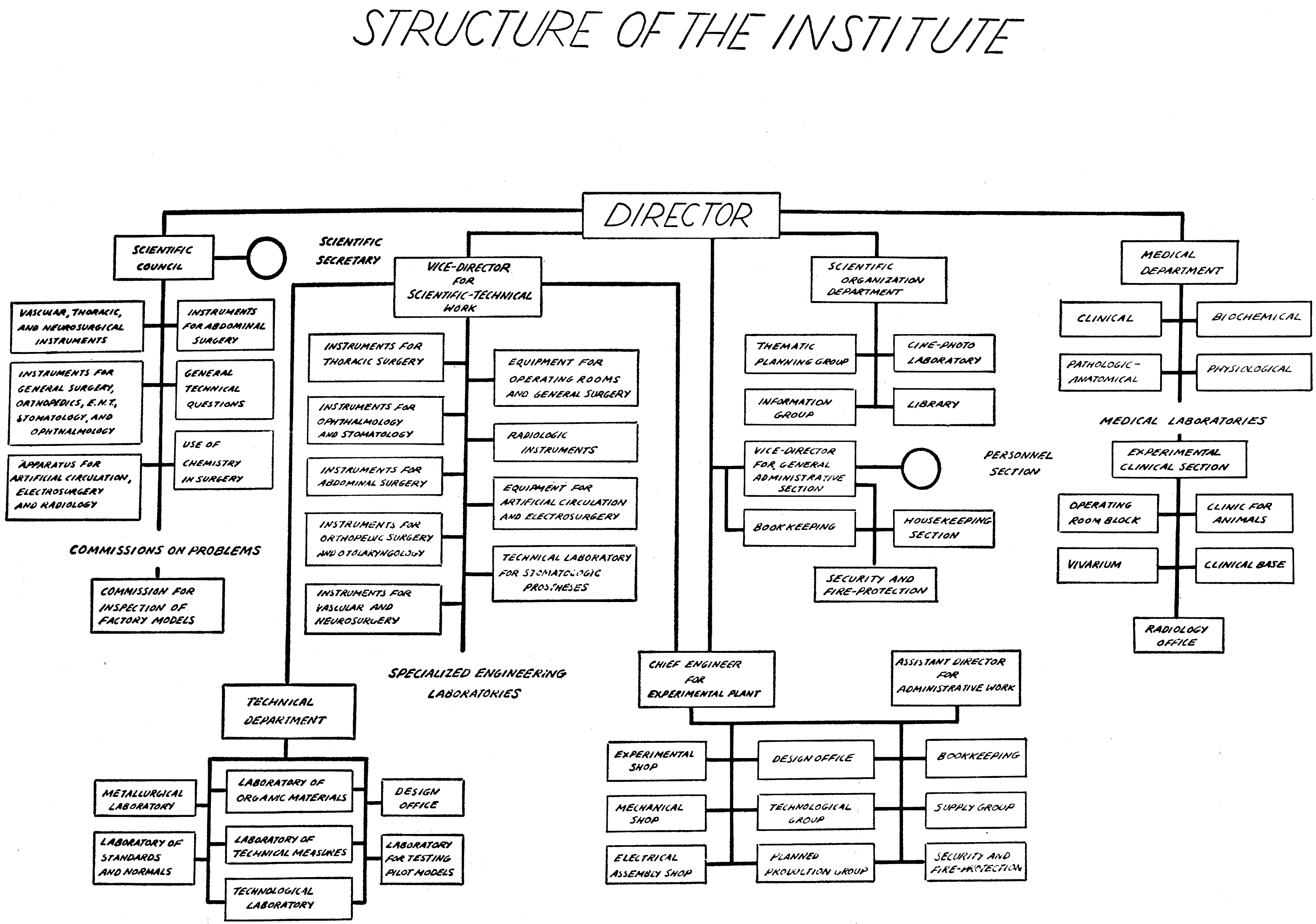
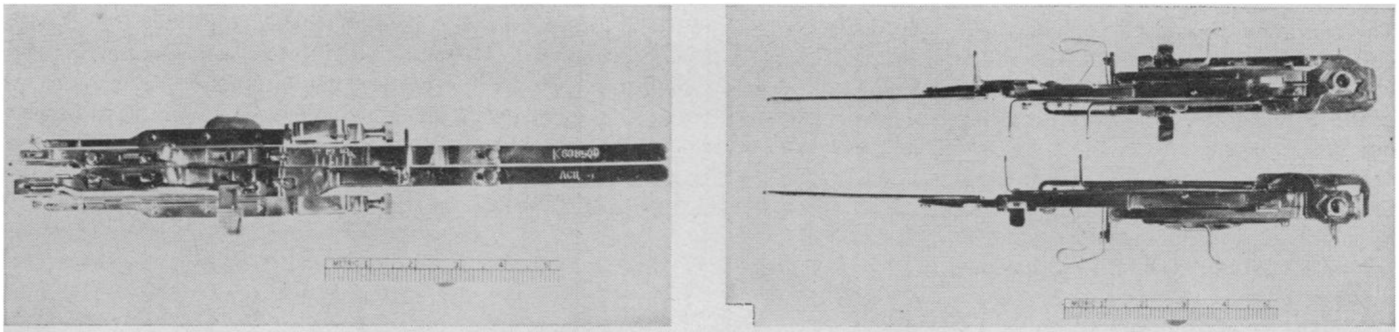


Fig. 1. Structural plan of the Scientific Research Institute for Experimental Surgical Apparatus and Instruments in Moscow. I do not know the significance of the circular symbols. [Reproduced with permission from the American Journal of Medical Electronics]



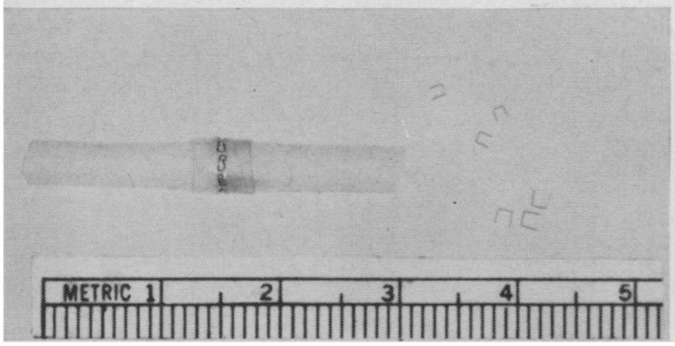


Fig. 2. (Top left) Russian blood vessel stapler, composed of two major parts as shown top right. (Bottom left) Model illustrating the principle of blood vessel anastomosis of mechanical stapling. The cuffed-back ends of the transparent model "blood vessel" have been joined together by the blood vessel stapler, using the tiny staples on the right. These have been bent into a B-shape by the stapler.

double row of staples is applied. The entire lung or lobe to be resected is then simply cut off along the edge of the clamp and removed. Berezovsky and Rosenberg (from Amosov's Clinic) report 11 bronchial fistulas (3.2 percent) and nine deaths in 341 pneumonectomies performed with this technique, and seven fistulas and three deaths after 250 simple lobectomies (*6*). They also report 512 "economic" resections of localized foci by wedge resection or apical resection without regard to segmental planes, with six fistulas and two deaths. It was impressive to note the simplicity and speed with which a completion pneumonectomy for tuberculosis in a patient who had previously had a lobectomy on the same side was carried out at this institute. Most other surgeons agreed that the incidence of bronchopleural fistula or empyema was not much affected by use of these devices, but they used them because surgery with them was faster, easier, and accompanied by less loss of blood. These claims have been substantiated at the Veterans Administration Hospital at Oteen, North Carolina (*7*).

Next most commonly used was the instrument for closure of the patent ductus arteriosus (*8*). With this device, a more delicate version of the lung-stapling instrument, two parallel rows of staples are placed across the patent ductus, the rows again being staggered with respect to each other. Ordinarily, the device is used twice—once at each end of the ductus which is not divided. In 50 operative cases in Leningrad there were no instances of recanalization. In Kiev the instrument had been used nearly 100 times, with two instances of recanalization, two instances of hemorrhage during the operation, and one instance of late hematoma, which absorbed and did not require surgery. I observed use of this instrument on one occasion in Kiev. The surgeon (Malakhova) took the precaution of freeing the entire area in order to place temporary tapes around the thoracic aorta proximal and distal to the ductus.

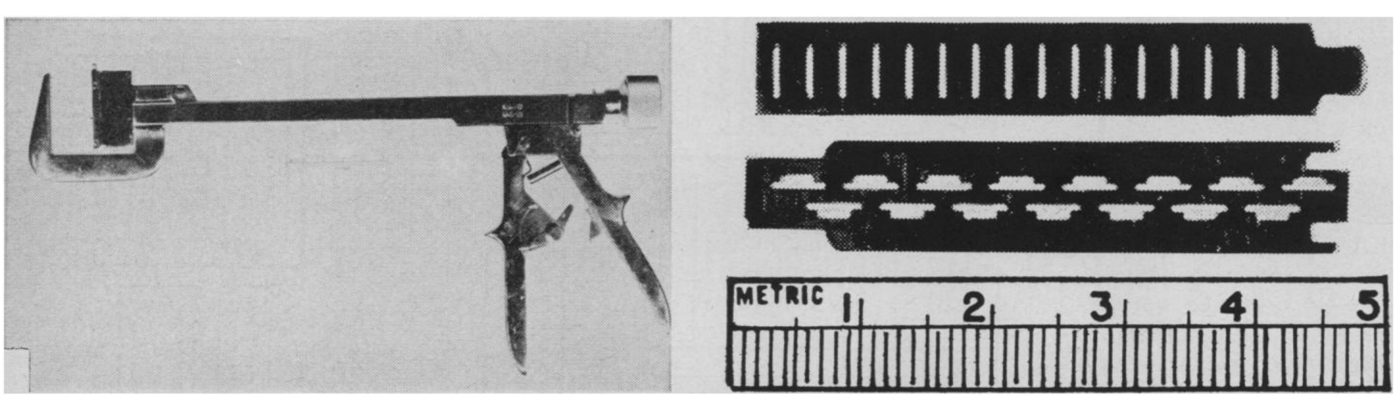


Fig. 3. (Left) Russian bronchus stapler. The lung stapler resembles this device superficially, as do the devices for stapling the patent ductus and the atrial appendage. (Right) This figure stresses the important difference between the bronchus stapler and the lung stapler. The top row shows the rack for holding staples in the bronchus stapler. Note that when this rack is placed across the bronchus, the staples are placed parallel to the long axis of the bronchus. The middle row shows the rack holding staples in the lung-stapling device. When used on hilar vessels or the bronchus, the staples are placed at right angles to the long axis of the structures. The same sized staples are used in the two staplers. The slots in the lower rack are different in shape only because each tooth of the staple driver in the lung-stapling device is reinforced for structural ability. Bottom row, metric scale.

The instrument was then applied at the aortic end of the short ductus, which was stapled; the clamp was opened gently and closed again to control oozing. Because the ductus in the case I observed was deemed to be too short for a second application of the device, the pulmonary side was occluded with a heavy ligature. The ductus was not divided.

Clinical opportunities for using the devices for vascular anastomosis, perhaps the best known of all these instruments, seem to be very limited even in Russia. This is not surprising when one realizes that relatively long segments of fairly normal vessels are necessary for either end-to-end or end-to-side anastomoses, and that the two vessels to be anastomosed end-to-side must lie at right angles to each other. While the devices have been, and still are, used extensively in the laboratory (*9*), reports of their clinical use seem to be limited (*10*). The instruments are rarely used in the vascular section of the Cardiovascular Surgical Institute in Moscow, but occasionally caval-pulmonary arterial shunts are performed, with their help, in cardiac surgery (*11*). I did not observe clinical use of the instrument during my 3 months in the Soviet Union. It is possible that there would be greater clinical application for an instrument less complicated and expensive than these Russian models, especially if the problem of loading the minute staples into the tiny bushings were eliminated. Such an instrument has recently been reported by Mallina *et al.* (*12*) (see Fig. 2).

Of interest also were the devices for stapling the gastric and duodenal stump, for anastomosing the esophagus side-to-side to the small bowel, and for suturing intestines end-to-end. Although opportunities to use such instruments arose during operations to replace occluded esophagi with segments of colon, Androsov and Petrov at the Sklifosovsky Institute in Moscow preferred to perform all of their anastomoses by hand. Androsov did use a special device to suture the distal blind end of the colon—to be introduced into the neck—but he invaginated this line with hand-placed sutures. Gritzman, of the staff of the Institute for Experimental Surgical Instruments, has written a monograph on the gastric suturing device (*13*), and Kalinina has written extensively on the intestinal suturing instrument (*14*), but, as I stated earlier, I did not have an opportunity to see these instruments used on patients. A neurosurgeon whom I queried in Leningrad regarding the nerve-suturing apparatus thought that it had little clinical application.

Discussion

In theory, at least, it might seem advantageous for the surgical profession to have at its service an institution devoted exclusively to the development of new surgical tools, or the improvement of existing ones. One might hypothesize that economically unprofitable but valuable ideas might thus eventually find practical application because their development had been subsidized, or that duplication of developmental or testing procedures, or proliferation of competing models of nearly identical instruments, or high costs resulting from the patenting of surgical inventions, might be avoided. One might expect the development of a host of practical instruments of high quality and advanced design to be the result.

In actual practice in Russia, however, only a few of these objectives seem to have been attained.

Paradoxically, even in the advanced experimental surgical laboratories of the institute, the home of such complex instruments as the stapling devices, ordinary box-lock instruments were unusual; rubber gloves were in woefully short supply; adhesive tape and its substitutes were nonexistent; intravenous fluids and blood were little used; the recording equipment was outdated; and instruments and sutures for fine vascular surgery were at a premium. In the surgical clinics I visited, undoubtedly the best equipped in the U.S.S.R., one cannot as yet see any significant effect of the institute on the general level of surgical instrumentation.

There seems to be no organization in the United States which is quite comparable to the institute. Its functions are divided, in this country, among private inventors; surgeons who collaborate as individuals with engineers; surgical instrument houses, and the growing bioengineering sections of some medical schools, clinics, and hospitals.

The National Institutes of Health maintain an Instrument Engineering and Development Branch of 63 men (*15*). At present, at least, the rich harvest from these diverse sources, in comparison to the achievements of highly organized, centrally planned medical engineering in the U.S.S.R., argue for our system. While it may seem wasteful of talent and energy, the more direct clinical orientation of instrument-development in our country and the wealth of ideas which seem to flourish in such a competitive atmosphere have apparently resulted in greater original contributions to the surgical world than have been made in the U.S.S.R. It seems plain that the spectacular advances of the Soviet Union into space are not reflected in similar spectacular advances in useful new surgical instrumentation —at least, they have not been up to the present time (*16*).

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