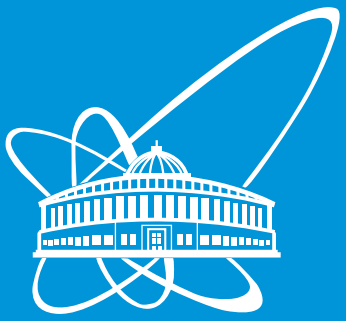

ОБЪЕДИНЕННЫЙ
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V.N.Pavlov

CRYOGENIC SURGICAL APPARATUS

Submitted to «Cryogenics»

2000

Introduction

This investigation has turned into a successful attempt to work out an optimum design of a cryogenic surgical apparatus (CSA) for practical medicine and cosmetology on a new basis [1-3]. The main point is the proper and fuller use of the thermodynamic properties of the readily available and most effective cryogen, liquid nitrogen, in compliance with the severe requirements to antiseptics of surgical instruments and safety.

The history of cryogenic surgery includes decades-long development of the method for freezing of biological tissues and hundreds, if not thousands, versions of useful instruments [4]. About 30 years ago the author of the present paper was involved in development of one of the first two cryogenic catheter in the USSR for removal of prostate. That attempt was stimulated by a successful operation of general De Gaulle in France but, unfortunately, remained unfinished. Since that time and up to now, despite appreciable progress in cryogenic technology, a reliable and convenient CSA has not been developed.

The limitation of almost all approaches to this problem was the use of the discharge under pressure as a method for delivering a cryogen to the tip of a cryogenic surgical instrument (CSI). It is discharge of a cryogen that made surgical instruments attractively simple and, on the hand, provided them with noticeable drawbacks, which any expert can name himself when comparing those CSI with the one based on the new approach to the technology and methods of cryogenic surgery.

Initial requirements

Based on freezing of tissues by liquid gases, cryogenic surgery places severe requirements on the apparatus. First of all, the CSA must be universal as much as possible, reliable, and safe both for the patient and for the surgeon. Their actual cooling power and ultimately low temperatures in the tip of the CSI must determine the duration of the operation, depth and the degree of destruction of frozen tissues. The surgeon must promptly intervene in the freezing process at any stage, watch the course of the process or program the CSA.

Apart from the initial requirements, development of a universal CSA involves some additional ones:

1. Selection or regulation of cooling power.
2. Direct cooling of tissues by a cryogen jet.
3. Freezing of tissue through replaceable tips of various shapes and sizes.
4. Protection of neighboring normal tissues against the direct effect of the cryogen.

5. Instantaneous supply and interrupt of a cryogen jet at any stage of the operation.
6. Automatic timing of freezing.
7. Prevention of the cold tip from sticking to the tissue or fast heating of the tip.
8. Thermal sterilization of the CSI.
9. Simple local or remote freezing control.
10. Automatic fixing of the CSI tip on the chosen area of tissue.
11. Light indication of tip operation.
12. Possibility of repeated instantaneous prolongation of freezing.
13. The distal part of the CSI made to allow cryogenic endosurgery.
14. Combined or parallel operation of the CSI and the endoscope.
15. Possibility of adapting the CSA to other low-boiling-point cryogens.

Description of the method and the CSA operation

The above-mentioned requirements logically lead to the only acceptable method of supplying the cryogen to the CSI tip. It is evacuation of the cryogen from a prechamber by a pump of sufficient capacity. The tip body must be the prechamber and nitrogen must be supplied to it through a siphon from a dewar or a vessel placed in the vacuum jacket of the CSI. The remaining units of the CSA are an electromagnetic actuator valve, a control panel with a timer, and a flexible vacuum line connecting the CSI with the vacuum pump.

Too many details about this type of CSA are not necessary for experts within the limited space of this paper. It is obvious that this design offers the following possibilities.

1. Overcooled two-phase liquid nitrogen, i.e. a cryogen of lower temperature, can be used, which speeds up the rise in the cooling power of a cycle and increases the temperature difference at the cryogen-cryoapplicator (tip)-tissue boundary.
2. An open-type tip can be used and the affected tissue can be directly irrigated by the two-phase jet of overcooled liquid nitrogen.
3. As soon as the cryogen supply is switched on, the tip is automatically stuck to the tissue and fixed to it because of a considerable decrease in the cryogen vapour pressure in the prechamber of the hollow tip. This way of fixing prevents liquid nitrogen from splashing out of the area within the inner chamber of the tip. Moreover, in case of accidental or involuntary shift of the tip the cryogen jet is immediately stopped because pressure difference disappears in the line of liquid nitrogen supply from a vessel with a normally boiling gas. It also allows a change in the operation technique: instead of

pressing the tip against tissue one can pull it together with the tissue stuck to it away from adjacent arteries or ganglions.

4. The liquid nitrogen jet can be controlled by a single «start-stop» button and the exposure can be set with a timer.
5. A desirable cooling power can be selected with a throttle in the cryogen supply line.

All the above advantages of the CSA were experimentally confirmed by model tests of two CSI displayed in Fig.1. The CSI with a thin (2.6 mm) and long (90 mm) distal end has a built-in vessel for liquid nitrogen, a control button, and a light indicator of tip operation. With 90 cm^3 of liquid nitrogen the CSI is capable of continuously operating for 8 minutes. The other version of the CSI combines a siphon and an outer dewar of rather large volume and is remotely controlled.

A typical course of freezing is displayed in Fig.2. The plotted data are obtained for a closed-type tip with a built-in heat exchanger. The diameter of a flat applicator is 10 mm. The water crystallization front is seen as a plane wave ending with an ice-water interface. Obviously, the temperature difference at this phase interface continuously decreases, therefore each selected cooling power must have its maximum distance between this interface and the applicator surface at which the cooling power is fully balanced by its dissipation in the liquid phase of the medium. When an open-type tip with an optical window of fluoroplastic tape is used, the two-phase nitrogen jet is clearly seen to hit the window and to spread over it practically simultaneously with pressing the «start-stop» button and to stop equally fast. Overcooling of liquid nitrogen to 70 K (-203°C) in the prechamber of the tip is confirmed by measurement of temperature and equilibrium vapour pressure.

Conclusion

Apart from its designed use, the described CSA model is well suited for experimental investigation on cryodestruction of tissues on the cell level. Using the result of the investigation, one can develop optimum designs of the CSA and devise techniques of various operations in patients. The CSA of two to three standard sizes may meet most cryogenic surgery needs. In addition, this work may result in development of endosurgical cryo-instruments.

The author is grateful to Dr. G.K.Gorlov and his co-workers for designing the compact control panel and the timer for the CSA and to the Directorate of the Laboratory of Nuclear Problems for their interest in this research.

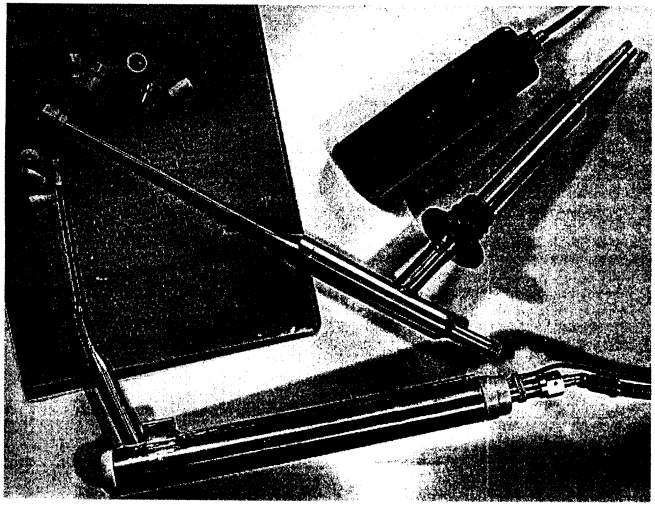

Fig. 1. Two variants of the cryosurgical instruments.

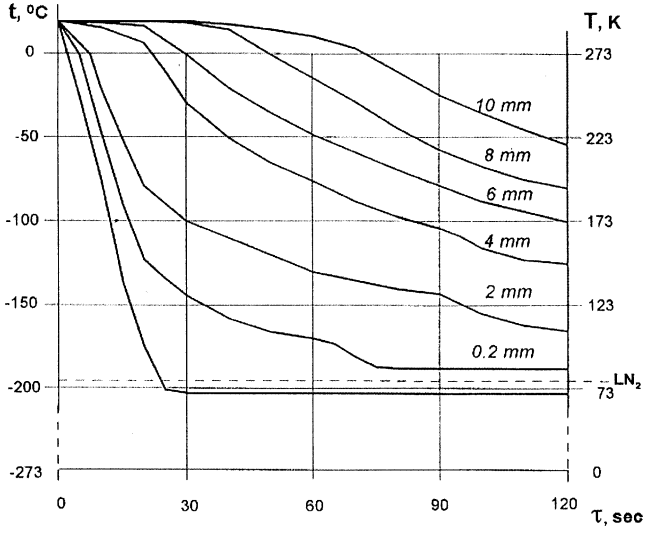

Fig. 2. The typical time dependence of water freezing inside the 15 mm cylindrical chamber. The numbers above the experimental curves show the distance of the copper-constant thermo-couple from the tip. The lower line is for the tip in the air.

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Павлов В.Н.
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Криохирургический аппарат

Предложен новаторский подход к разработке криохирургического аппарата нового поколения для выполнения операций методом глубокого замораживания биологических тканей не нагнетанием хладагента, а с помощью откачки переохлажденной двухфазной струи жидкого азота. Приводится общее описание метода и результаты предварительного испытания первого варианта криохирургического инструмента.

Работа выполнена в Лаборатории ядерных проблем им. В.П.Джелепова ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 2000

Pavlov V.N.
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Cryogenic Surgical Apparatus

A novel approach is used to develop a new-generation cryogenic surgical apparatus which deeply freezes biological tissues with a two-phase jet of liquid nitrogen. A general description of the underlying deep freezing method is given and tentative test results for the first version of the apparatus are reported.

The investigation has been performed at the Dzhelepov Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 2000

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