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# Ultrasonic aspiration in neurosurgery

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## Summary

A short review describes the equipment of the ultrasonic aspirator CUSA, the microscopic and ultramicroscopic changes of brain tissue exposed to ultrasonic aspiration, as well as the indications and clinical experience in brain tumour operations.

**Keywords:** Experimental and clinical experiences, ultrasonic aspiration in neurosurgery, technique.

## Introduction

It is by no means unusual that instruments or techniques developed in one medical specialty outgrow their original purpose and provide excellent services to other specialties. Ultrasonic aspiration is a typical example of this phenomenon. The original idea is about 20 years old and was developed by C. D. Kelman, an ophthalmological surgeon, with the purpose of treating cataract by a procedure he named phacoemulsification [6, 7]. In fact, this instrument was primarily designed to be an ultrasound knife. After a short time, however, neurosurgeons and general surgeons realized the tremendous potentialities of this instrument, which underwent several improvements until the present form was reached. Also, a series of clinical and experimental studies were published on ultrasonic aspiration in neurosurgery and general surgery [1, 2, 3, 4, 5, 9, 10]. It was established that ultrasonic aspiration produced no deleterious physiological effects on nervous tissue [10].

Nowadays ultrasonic aspiration may be considered part of the everyday routine of an updated neurosurgical operating theatre. By adequately setting the controls of the computer-steered aspirator, one may achieve the functions of (1st) aspiration, (2nd) cutting and (3rd) coagulation.

## Description of the equipment

The ultrasonic aspirator CUSA* (Fig. 1) consists essentially of a central steering unit, a handpiece and a control pedal. The central steering unit is mobile, and the handpiece may be submitted to gas sterilization.

The handpiece (Fig. 2) contains a hollow titanium tip which oscillates longitudinally along its axis, driven by a magnetostrictive transducer. Oscillation occurs with a frequency of 23 kHz (23000 times per second), which corresponds to ultrasound. The longitudinal vibration of the titanium tip destroys cell membranes by its "hammering effect". The total extent of tip oscillation is 300 μ and may be regulated in the central steering unit.

Since the high-frequency vibration causes marked production and liberation of heat, the aspirating core is enveloped by a protecting sheath which serves for irrigation of the tip. For this purpose, physiological saline coming from a commercial infusion bottle is used. Irrigation intensity can be changed as needed in the central steering unit, the irrigation solution being propelled by a roll pump. When irrigation is kept very low, the heat developed by ultrasonic aspiration can be used for cutting or coagulating purposes. It will effectively obliterate vessels with a diameter of less than 2 mm.

Suction, which can also be regulated at the central steering unit, serves to remove the tissue fragmented by the vibrating tip as well as the irrigation through it.

The central steering unit contains the electronic circuits as well as the suction, irrigation and cooling systems. All functions are computer-regulated.

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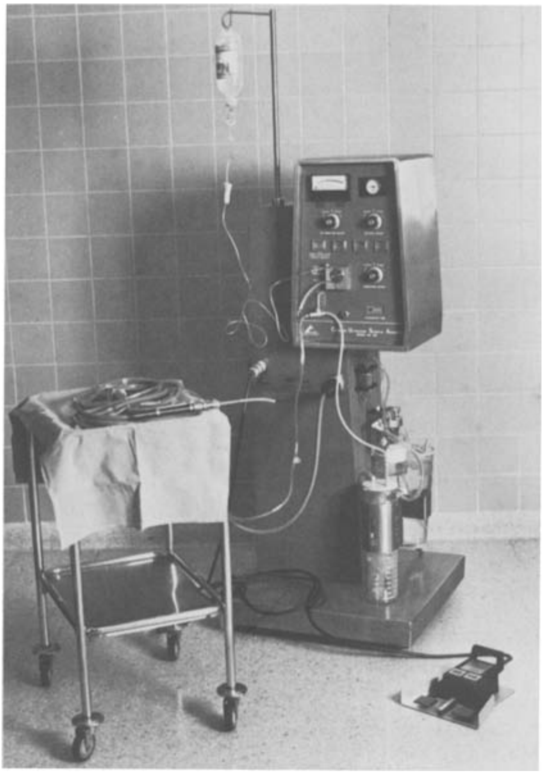
* Cavitron Corporation, Stamford, Connecticut



Tip vibration can be continuously regulated up to 75 watts, which corresponds to the maximal vibration length mentioned above.

A series of switches in the front plate of the steering unit makes its use very easy. These switches contain green and red lamps and are put in action one after the other, whenever the corresponding green lamp is on. This makes its use extremely simple.

Suction is also regulated in a continuous fashion from 0 to 60 mm Hg.

Irrigation can be regulated from 1 to 50 ml/min.

A timer records the time for which each tip has been used. The manufacturer recommends that total utilization time for each tip should not surpass 30 min, but we have been able to re-use a tip for much longer periods.

The pedal serves to trigger aspiration and/or irrigation. It works on an on/off basis and plays no role in the fine regulation of these functions.

◁ Fig. 1. CUSA equipment. Central steering unit (background), triggering pedal (on the floor) and handpiece (on the tray).

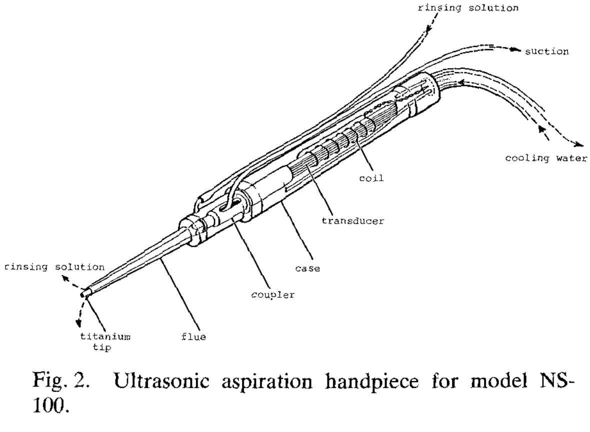


Fig. 2. Ultrasonic aspiration handpiece for model NS-100.

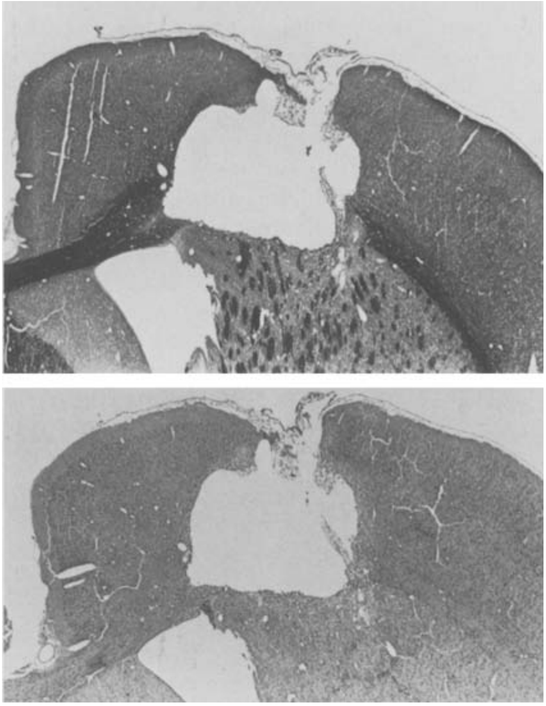


Fig. 3. Seven days after ultrasonic aspiration in the rat ▷ cortex, the necrotic and haemorrhagic tissues have been cleared, the aspiration cavity shows clear-cut borders, and there is practically no surrounding oedema, as shown both by myelin stain according to Weigert (upper section) and by haematoxylin-eosin (lower section). Magnification: approx. 70×.

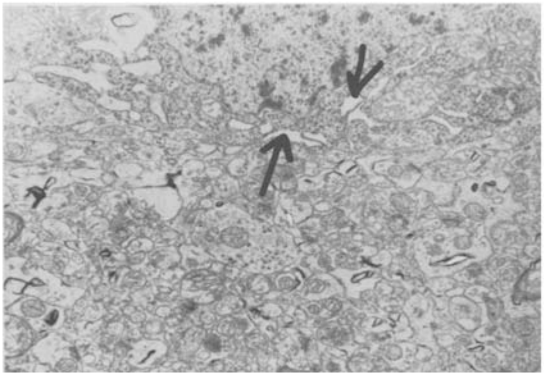


Fig. 4. Rat cortex neuron 24 h after neighbouring ultrasonic aspiration: marked dilatation of endoplasmic reticulum (8000×).

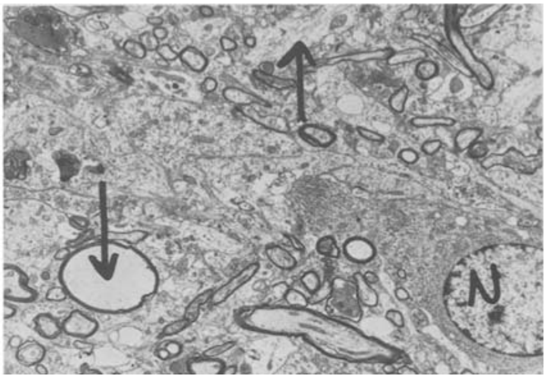


Fig. 5. Subcortical white matter of the rat 72 h after neighbouring ultrasonic aspiration: marked swelling of myelinated and unmyelinated axons in the perifocal zone (3500×).

## The "tactile feedback"

Manipulation of the ultrasonic aspirator gives the neurosurgeon a very accurate tactile sensation of the consistency of the tissue with which the aspirator establishes contact. This sensation is different from that obtained when using conventional suction. It represents a great advantage as compared to "touchless" methods, such as laser irradiation, since it permits a very fine ("epicritic") control of the surgeon's movement. Since, additionally, effectiveness of ultrasound aspiration depends on the amount of water contained in the tissue, the surgeon sometimes virtually feels the transition between the parenchyma of a tumour and its vascular "stroma". This permits a very "protective" handling of the aspirator and a selective aspiration of tumour tissue. According to the intensity of suction and of aspiration chosen by the surgeon, it is possible to carry out intracapsular tumour removal in a safe, rapid and easy way. There is no traction on tissue and, as pointed out by Flamm et al. [1] "steady contact with tissue is never made".

This "tactile feedback" has proven extremely useful in difficult tumours, such as meningiomas of the skull base and acoustic neurinomas.

## Experimental studies

Only Flamm et al. [1] and Young et al. [10] have studied the histological changes produced by ultrasonic aspiration in nervous tissue. In a recent paper of Tamburus et al. [8], we have been able to show experimentally that ultrasonic aspiration reduces the boundary zone between the aspiration cavity and normal nervous tissue in the brain. Perifocal tissue damage caused by ultrasonic aspiration is only minimal as compared to that caused by conventional aspiration and subsides much faster (Fig. 3).

Brain tissue exposed to ultrasonic aspiration has also been submitted by us to electron microscopic studies. After ultrasonic aspiration of a circumscribed area of the rat cortex, adjacent tissue divided into three zones:

1. the necrotic area proper,
2. the immediately adjacent zone, and
3. perifocal areas appearing intact on conventional light microscopy.

Tissue was obtained 24 and 72 hours after ultrasonic aspiration.

Twenty-four hours after ultrasonic aspiration, brain cortex reveals a marked dilatation of endoplasmic reticulum of neurones. Both neuronal and glial cells have large vacuoles. There is swelling in myelinated and unmyelinated axons (Fig. 4).

At 72 hours, axonal changes persist in the perifocal areas and in those regions which appeared normal on light microscopy. In addition, axons frequently contain vesicles of variable size. There is a prominent cortical and subcortical oedema (Fig. 5). Phagocytes are increased in number in the perivascular spaces. Small vessels, on the contrary, appear to be intact in the vicinity of the lesion. These ultrastructural changes correspond to those observed following mechanical lesions of nervous tissue. We were unable to observe any specific changes, especially in cell organelles, which could be ascribed to ultrasonic aspiration. Such differences, if at all present, are only quantitative. More than one year's continuous experience with ultrasonic aspiration has permitted clear recognition of its advantages and limitations. It adds a new dimension to surgery of convexity meningiomas, meningiomas of the base of the skull, chordomas of the base of the skull, cerebellopontine angle tumours, spinal tumours, meningiomas of the sphenoid wing, gliomas, cerebral metastases, giant aneurysms, etc. As yet, we have no experience with the use of ultrasonic aspiration in (cervical or lumbar) disk disease.

It is our feeling that aspiration rather than coagulation or cutting is the main advantage of CUSA. It has been possible to "empty" acoustic neurinomas without damaging their capsule. It has also been possible to remove completely medial sphenoid wing meningiomas which surrounded the carotid siphon without the slightest damage to this artery (although the ultrasonic aspirator was directly applied to its wall). There is no doubt that ultrasonic aspiration permits the removal of many a tumour which must necessarily be considered inoperable if one is restricted to the cautery loop and conventional aspiration. There is no doubt, furthermore, that a given surgeon will be able to increase the rate of "operability" of his patients if he is able to use ultrasonic aspiration. The currently available handpiece (model NS-100) may prove to be too heavy and too short for lesions located deeply and in restricted operative fields. At present, there are new designs (curved handpiece, longer handpiece) which, however, have some technical limitations.

The ultrasonic aspirator is a highly specialized device. It requires gentle manipulation and careful treatment. Damage to the handpiece may become extremely expensive. Our experience has shown that it is absolutely necessary to train the nursing personnel regarding handling of the equipment in general and of the handpiece in particular.

As a whole, the utilization of ultrasonic aspiration

1. increases safety,
2. reduces operating time,
3. improves quality and
4. facilitates selective surgery.

There are no known contraindications. There are only limitations (financial, personal, etc.), which, however, will necessarily remain circumstantial.

Ultrasonic aspiration is a major achievement, as was bipolar coagulation and the operating microscope, and has already become a "must" in neurosurgery.

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