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Use of Electric Welding of Living Tissues in Surgery (review)

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Welding is used in many areas of surgery. Due to its use, operation times are decreased, as is the probability of post-operative complications. This method is convenient to use where it is difficult or impossible to use sutures, clips, or staples.

Electric welding is used in surgery for incisions, hemostasis, and joining tissues. Tissues are compressed using electrodes, through which a high-frequency current is passed. Temperature and the electric field produce changes leading to the formation of welded junctions. The welding site consists of a tight junction of bundles of elastic, collagen, and smooth muscle fibers. The main mechanism forming junction is fusion of muscle and collagen fibers and gluing via "DNA/protein-associated autobioglue" [1-4]. These phenomena are not seen with conventional electrosurgery. Studies at the E. O. Paton Electric Welding Institute (EWI), National Academy of Sciences of Ukraine, addressing this method have been under way in collaboration with medical organizations since 1992. US, Russian, and other patents have been secured [5-8]. This review describes the use of welding as introduced into the field of surgery.

Use of welding in hemostasis and tissue incision. Welding of small-diameter vessels uses special forceps, while clamps are used for large-diameter vessels (Fig. 1).

Technical points have been addressed in [9-11].

As the frequency of the welding voltage increases, the effect of displacement of the current to the outer surface of the electrode becomes more pronounced [12]. This has to be considered when developing new effective surgical electrical instruments.

An independent expert evaluation of welding using equipment from the EWI was carried out in the US in relation to arteries in 70-kg pigs. Arteries of diameter 2-8 mm and aortas of diameter 12 mm were welded. The mean junction strength was seven times greater than the normal systolic pressure (940 ± 84 mm Hg).

There are two methods for incision of tissues with simultaneous cautery of vessels. In the first, welding clamps or forceps are used to produce initial heating of tissues, which are then incised. In the second, special forceps and clamps are used which simultaneously incise and produce hemostasis [13].

Hemostasis is obtained by formation of a junction of glue-like biomass, vessel spasm, and the formation of thrombotic masses in the welding zone [3, 4]. Sections do not show necrosis, and pink muscle tissue retains viability [1]. Instruments for incision have narrower electrodes [14].

Instruments with two fixed electrodes separated by an insulating layer are used for the homeostasis of parenchymatous organs and terminating capillary bleeding. A current passes through the tissue between the electrodes to coagulate blood and cauterize vessels [15].

Decreases in the thickness of the insulating layer lead to increases in tissue temperature, facilitating incision with simultaneous hemostasis [16].

Bipolar instruments with flexible conductors are used in endoscopic operations to stop gastrointestinal bleeding.

Use of welding in oncological surgery. Tumors have intensive blood supplies. Vessels must be sealed without spreading tumor cells. Due to rapid hemostasis, welding significantly decreases the duration of surgery, produces a several-fold reduction in blood loss, and ensures aseptic and hermetic sealing at junction sites. The absence of suture materials prevents complications associated with the body's response to foreign bodies [1, 3, 17].

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a b

Fig. 1. Welding of an artery (a) and the welded vessel (b).

Patients are admitted for surgery after courses of radio- and chemotherapy. These weaken the immune system and decrease the body's wound healing capacity. Use of thread sutures to join wound margins leads to purulent and inflammatory processes and the absence of tissue intergrowth. Welding directly connects tissues, which has favorable effects on the post-operative period. In removal of brain tumors, welding is used for hemostasis and welding of implants used for closing defects in the dura mater.

Welding is used for restoring the patency of the fallopian tubes in infertility or extrauterine pregnancy. Operations promote retention of the childbearing function of the placenta and can be performed by both open and laparoscopic methods. For removal of ovarian cysts, a clamp is used to heat the pedicle, which is then incised and removed. Welding is used effectively for dissecting adhesions, removing myomas, artificial termination of pregnancy, and open and vaginal hysterectomy [1]. Welding decreases blood loss by 70%, halves the duration of surgery, and reduces the probability of post-operative complications by 80% [4].

In pediatric surgery, it is very important to decrease the duration of surgery, reduce blood loss, ensure safety, and avoid burns. Welding is therefore used in neonates, for circumcision, removal of Meckel's diverticulum and hemangiomas, and in the treatment of patients with coagulopathies and von Willebrand's disease [1].

In laparoscopic surgery, tissues are joined and vessels and ducts are sealed using clips or staples, which increases the cost of surgery and can lead to foreign items being left in the body. Sites at which staples penetrate tissues prevent full hermetic sealing. Clips can slide off sealed vessels and ducts, producing complications. Welding ensures hermetic junctions, and heat does not spread to the surrounding tissues. Joints include many tissue components, including undamaged cells, creating conditions for subsequent recovery [18].

Welding tools are used not only for welding, but also for mobilizing organs and manipulating them, which is convenient for the surgeon, especially in single-incision laparoscopic surgery (SILS), which is performed through a single incision in the area of the umbilicus [19].

In cholecystectomy, a single welding instrument is used to separate the vessels and ducts and then apply welding. Welding in the treatment of acute appendicitis avoids drainage, creates an antimicrobial effect at suture sites, hermetically seals the lumen of the appendix, decreases the probability of post-operative complications, and reduces time spent in hospital [1, 20].

Bipolar laparoscopic instruments are used for welding air-containing vesicles (bullae) around 1 cm in diameter on the lung surface in the treatment of spontaneous pneumothorax. In welding, bullae are coagulated, become wrinkled, shrink, and are firmly welded to lung tissue. This avoids complex surgery with resection of the damaged part of the lung [1, 15, 21].

Laparoscopic welding is used in splenectomy, in the removal of tumors, adrenals, and cysts, and for the marginal resection of the liver and lungs. Welding is reliable and effective when recommendations are followed [22].

In welding, the specific pressure of the electrodes on tissues must reach 1.5-2 N/mm^2. Special measures must be taken to transmit strong forces to the electrodes [23, 24].

Scalpel incision of the **parenchymatous organs** is accompanied by high blood losses, while suturing with filaments or staples is inconvenient because of the low tissue strength and lack of hermeticity. Resection of an organ with simultaneous hemostasis using welding provides hermetic suturing with a minimal thermal action zone, ensures good economy of surgical and suture materials, and decreases operation time and post-operative treatment. Lymphorrhoea, necrosis, and detachment on removal of significant quantities of tissues and organs do not occur. Welding provides bleeding-free removal of tumors and cysts; it is used in echinococcectomy, sealing of lung and liver wounds, and patch surgery of lung defects for the treatment of emphysema [1, 25, 26].

In multiple trauma, welding complies with the "golden hour" rule, reduces blood loss, and restores the anatomical integrity of pancreas, liver, and spleen [27].

In endovitreal surgery in **ophthalmology**, monopolar instruments are used for incision, hemostasis, welding, and manipulations, providing for surgery without opening the eyeball (Fig. 2). In removal of intraocular melanomas and hemangiomas, it is used to provide reliable hemostasis, ensuring ablastic conditions and retention of vision [28-30].

As compared with laser coagulation, welding of the retina to the choroid is less traumatic, quicker, and has a lower probability of complications [31].

Removal of the eyeball with subsequent welding of the conjunctiva is performed using special instruments without use of suture material. Welding sites form conglomerates of degraded tissue elements, denatured proteins, collagen fibrils, and thin-filament "felt-like" material sealing the wound surface [32, 33].

Welding is used for resection and removal of the adrenals and thyroid, pancreas, and parotid gland surgery. Welding decreases surgery duration by 30% and blood loss by 20-50%, and produces a manifold reduction in post-operative complications [1, 26, 34, 35].

Welding of the intestine is a simpler and quicker procedure than suturing. The absence of foreign material decreases inflammation and adhesions even in diffuse peritonitis. Decreases in collagen formation counter excessive scar formation [36].

Welding can be used to join different organs: the bile ducts and the small intestine, or the intestine and the stomach [1, 37, 38].

The technique of welding the appendix is simple in use. Welding reliably and hermetically seals the appendix and produces an antimicrobial effect [1, 20].

Instruments for simultaneous welding of the intestine by open and laparoscopic approaches have been developed at the EWI. In contrast to staplers, no staples are left in the body and joins retain hermeticity at high pressure (Fig. 3); the technique is simpler than thread suture [1, 8].

In proctology, welding is used for mobilization of the large intestine, colectomy, and formation of colo- or ileoanal anastomoses. Welding is used for sealing anal fissures and rectal fistulas and for polypectomy. The techniques for treating hemorrhoids by welding were developed at the end of the 1990s and are now widely used throughout the world. They decrease the duration of surgery, in-patient duration, blood loss, and post-operative pain [1].

Patients with **cancer of the throat** stage 3-4 receive pre-operative courses of radiotherapy, which weakens immune status. As a result, thread sutures produce impairments to blood supply and allow migration of microorganisms along the filaments, which can lead to purulent complications; allergic reactions to foreign bodies can occur, as can the development of inflammatory and edematous changes to tissues; fistulas can also form. Welding joins tissues hermetically, decreases pain, and provides for the formation of artificial vocal cords (Fig. 4) [17, 39].

In ENT surgery, special instruments for blood-free resection, coagulation, and welding have been developed and patented. These contain a pair of electrodes of different shapes separated by an insulating layer. Removal of papillomas, adenoids, and tonsils or reductions in their sizes are performed without bleeding; surgery duration is

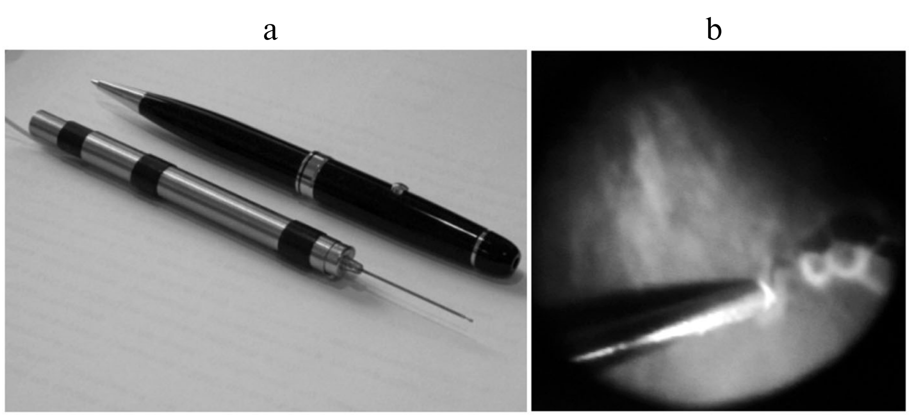

Fig. 2. A monopolar instrument for intraocular surgery (a); welding of the retina to the choroid (b).

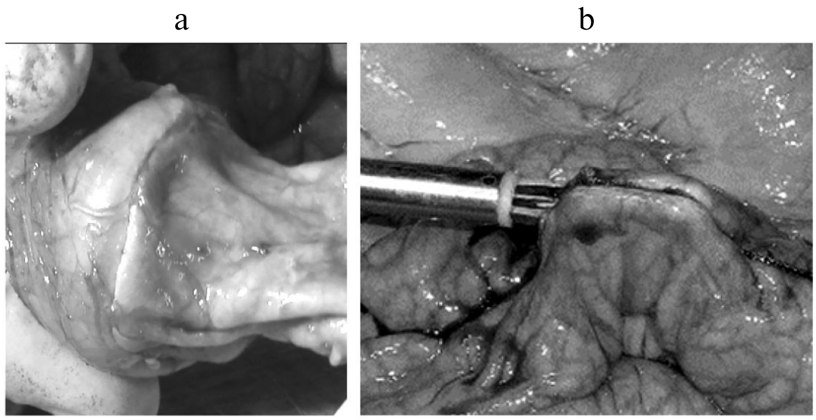

Fig. 3. Simultaneous welding of the intestine: a) “end to end” welded suture; b) “side to side” weld of intestine with laparoscopic instrument.

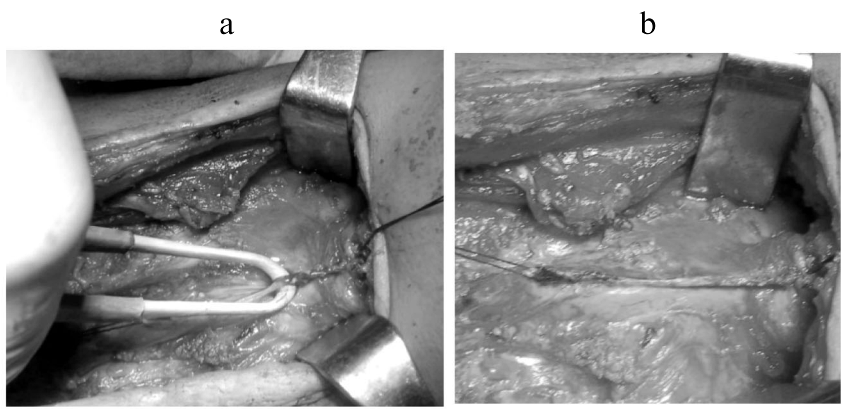

Fig. 4. Welding of pharyngeal-esophageal fistula (a); welded suture (b).

decreased, and post-operative complications do not occur. In the treatment of nasal septal deviation, this structure is mobilized using a bipolar electric scalpel and is welded with forceps [1, 16, 40].

Use of welding in urological surgery has potential for: resection of the kidneys, pyelolithotomy with subsequent reconstruction of the renal pelvis by electric welding, ureterolithotomy followed by restoration of the integrity of the ureter by application of a weld suture, production of ureteroureteric anastomoses of the end-to-end type, electric welding of longitudinal sections of the bladder wall, reconstruction of the bladder using segments of ileum, and adenomectomy [1, 41].

In organ transplantation, welding decreases the probability of hemorrhage and lymphorrhea, is less traumatizing to the tissues, and provides better functioning of transplants [42].

In the treatment of burns, skin flaps are attached to wound surfaces by welding. In **vascular surgery**, prophylaxis against thromboembolism of the pulmonary artery is obtained by blockade with floating thrombi [1]. In mediastinal surgery, welding decreases the probability of injuring vitally important organs. Bipolar welding probes are used for hemostasis after removal of veins in the surgical treatment of varicose veins. Cooling with physiological saline facilitates movement of instruments and decreases tissue damage.

Welding in the treatment of hernias. Welding of the peritoneal margins over mesh implants is a simple, reliable, and safe method in which there is no need for additional use of sutures and fixing material. Suppuration of surgical wounds does not occur and no smoke or unpleasant odors are produced [1, 26, 43].

Laparoscopic surgery is performed in a “dry” surgical field. The duration of surgery is decreased and techniques are significantly simplified. Decreases in the operation duration and recovery periods lead to reductions in the costs of medications, including narcotics [44].

In veterinary surgery, welding us used in general surgery, traumatology, castration and sterilization of animals; it decreases operating times by factors of 3-4 and significantly reduces blood loss and pain. Special instruments and larger power supplies with greater outputs are needed for large animals.

Conclusions

Welding of living tissues decreases surgery duration and blood loss and leaves no foreign objects in the body. It has greatest potential in those areas of surgery where it is inconvenient or impossible to apply thread sutures.

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