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Low-voltage coagulation for welding sutures watertight: an experimental study

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Summary. A rat model was developed to test the watertightness of sutures. In this model it was proved that welding by use of low-voltage coagulation current did not improve on the watertightness obtained with conventional skin suturing. The mean leak pressure after welding was about 4.2 cm H_2O, i.e. statistically significantly lower than the mean leak pressure of the conventional suture, which is 14.1 cm H_2O. Neither addition of protein solder nor an additional conventional suture improved these results. It is therefore concluded that low-voltage coagulation is unsuitable for welding tissues.

Key words: Welding – Watertight – Suture

A few years ago experimental microwatt CO_2 laser tissue welding was described, with encouraging results in reconstructive surgery of the urethra [1, 4, 5]. The aim was to obtain a watertight suture, which can avoid urinary diversion in several surgical procedures (e.g. hypospadias surgery) or at least shorten the duration of it. A watertight suture can also avoid the noxious effects exerted by urinary extravasation, especially if infection is present, on wound healing, and thus diminish fistulization and fibrosis.

Bipolar low-voltage coagulation has essentially the same effect on tissues. It generates heat, which coagulates the proteins between the two poles of the coagulation pincet. The only major difference consists in the diffusion of that heat in the surrounding tissues, which is more widely dispersed than when using a CO_2 laser. However, as the bipolar coagulation equipment is much less expensive than the laser, and is also commonly available, it seemed it would be a good idea to evaluate its possible application as a welding device in urology.

Materials and methods

Experiments were done on male Wistar rats weighing between 200 and 220 g. After 12 h fasting and preoperatively antibiotics (thiamphenocol 25 mg/kg body wt.), animals were anaesthetized with pentobarbital (25 mg/kg body wt., i.p.). The abdominal wall was shaved carefully, and after disinfection it was incised in an inverted U-shape through its full thickness. Both sides of the U incision are dissected so that a skin tube can be easily sutured without traction. The skin remains attached to its vascularization through its subcutaneous tissue. The skin flap obtained is sutured with a running 4.0 chromic catgut to a bind-ending tube open on one side.

To test the watertightness of the suture line, which was done immediately after surgery while the animals were still anaesthetized, a connector is introduced into the open end of the skin tube, and a suture placed around it prevents leakage of fluid between the tube and the connector. The latter is connected by a tube to a small water reservoir, which can be raised progressively along a measuring scale.

A dilute methylene blue solution is used to demonstrate leakage along the suture line. By raising the fluid column, a hydrostatic pressure is created in the skin tube. The fluid column is raised in a standardized way at the rate of 1 cm every 30 s. The pressure (cm H_2O) at which leakage is observed is recorded.

To weld the tissues a bipolar forceps was used. The current was applied through a coagulation device (Valley Lab, Colo., USA) adapted so that current leakage was as small as possible, in order to produce a low voltage current. The edges of the skin were grasped in the forceps and current was given until coaptation was observed. This was done every 1 mm along the suture line.

To weld with a solder the same procedure was used, but the edges were impregnated with human albumin. Coagulation of the solder is easily observed, as it turns white on coagulation. The effect of welding was investigated in both cases at 1 and at 2 W.

Results

The leakage pressure after welding with and without solder as compared with conventonal suturing is given in Table 1 as a function of the power. An *F*-test shows that the variances of the measurement for groups IIa and IIb and for IIIa and IIIb are homogeneous (respectively $P > 0.20$ and $0.10 < P < 0.20$). Moreover, according to a *t*-test the mean leakage pressure at 1 W does not differ significantly from that at 2 W for group II ($P > 0.50$) or for group III ($P > 0.50$). This indicates that the welding power has no significant effect on the leakage pressure. Consequently, the data recorded in the subgroups for groups II

Table 1. Hydrostatic leak pressure (cmH_2O) immediately after conventional suturing, welding, and welding with solder

Group	I	II a	II b	III a	III b
Method	Conventional suturing	Welding (1 W)	Welding (2 W)	Welding (1 W) + albumin	Welding (2 W) + albumin
	16	7	4	5	4
	12	5	5	2	3
	10	2	7	1	6
	17	3	2	7	5
	9				
	15				
	18				
	16				
Mean	14.1	4.3	4.5	3.8	4.5
		4.4		4.1	
Standard deviation	3.4	2.2	2.1	2.8	1.3
		2.0		2.0	

Table 2. Hydrostatic leak pressure (cmH_2O) immediately after conventional suturing and welding and after conventional suturing and welding with solder

Group	I	IV a	IV b	V a	V b
Method	Conventional suturing (CS)	CS + welding (1 W)	CS + welding (2 W)	CS + welding (1 W) + albumin	CS + welding (2 W) + albumin
	16	10	10	7	10
	12	12	7	9	12
	10	17	9	12	9
	17	9	8	13	10
	9				
	15				
	18				
	16				
Mean	14.1	12.0	8.5	10.3	10.3
		10.3		10.3	
Standard deviation	3.4	3.6	1.3	2.8	1.3
		3.1		2.0	

and III can be pooled, resulting in mean values for the leakage pressure of 4.4 and 4.1 $cm H_2O$, respectively, for groups II and III. A Levene's test shows that the corresponding variances of the pooled data for these groups do not differ significantly from each other or from the variance on the measurement found for control group I ($0.05 < P < 0.10$). However, an ANOVA analysis demonstrates that there is a significant difference in the mean leakage pressure for groups I, II and III ($P < 0.001$). According to a Newman-Keuls' multiple range test, at the 95% confidence level the mean leakage pressure decreases in the order: group I $\gg$ groups II = group III.

This indicates that the leakage pressure of about 4.2 $cm H_2O$ obtained after welding is not influenced by the use of solder, but is drastically lower than that obtained with conventional suturing (14.1 $cm H_2O$).

Table 2 summarizes the leakage pressures when conventional suturing is combined with welding at a power of 1 or 2 W and with or without application of solder. The variances of the measurement for the subgroups a and b are homogeneous according to a F-test for group IV ($0.05 < P < 0.10$) as well as for group V ($0.10 < P < 0.20$). On the basis of a t-test it is also found that the mean leakage pressure of the subgroups do not differ significantly for group IV ($0.1 < P < 0.50$) as well as for group V ($P > 0.50$). This result confirms the observation that the welding power has no influence on the leakage pressure so that the data of the subgroups a and b can be pooled for group IV as well as for group V. According to Levene's test the variance of the leakage pressure for the control group I and the combined groups IV and V are homogeneous ($P > 0.20$). However, an ANOVA analysis clearly shows that the mean leakage pressure for these three groups differ statistically significantly ($0.01 < P < 0.025$). On the basis of a Newman-Keul's multiple range test at the 95% confidence level, the mean leakage pressure is found to decrease in the order group I > group IV = group V.

This again indicates that the leakage pressure of about 10.3 $cm H_2O$ obtained with welding is not affected by the use of solder. Moreover, it appears that the application of welding in addition to conventional suturing has a negative effect, or at best no effect, on the watertightness.

Discussion

Welding of tissues with a laser was first done in 1980. Microvascular anastomosis could be created successfully by this technique [2]. In urology welding was used by Merguerian and Rabinowitz [3]. They welded ureters, and their results were equivalent to those obtained with conventional suturing. In 1988 Poppas et al. published their first animal experiment with welding for urethral reconstruction [5]. In rats, partial transsection of the urethra was repaired using three different techniques. For microsuture their success rate was 50%; for laser welding 58%; and for laser welding with a solder, 90%. "Success" in this experiment meant healing without complications. The conclusion reached was that laser welding using a solder was superior to microsuture. The experiment was extended to free skin graft repair for urethral defects, and the same superiority of welding with solder was found.

Another group [1] had encouraging results with laser welding in skinflap surgery for the urethra.

In our experiments an objective parameter, watertightness, was used to evaluate the success of new suturing techniques. It was shown that tissue welding using low-voltage coagulation is not a suitable alternative to conventional suturing. In fact, it is proven that welding, even when combined with solder, makes suture lines less watertight than those obtained with conventional suturing. A conventional suture could not even be made more watertight by welding it.

What is the explanation for these results? The first problem is the equipment. It is very difficult to know exactly how low is the energy delivered at the tissues. Owing to current leaks in the generation of the coagulation current, the bipolar equipment does not always deliver the same low current. In the lower energy ranges used for the experiments in this study, small current leaks are proportionally more important.

Another problem lies in the fact that welding with bipolar forceps is a touch-technique. Sometimes it was observed that tissues stuck to the forceps so that the weld was disrupted on retraction of the forceps.

The success of laser welding depends heavily on the possibility of focusing the energy on a very small amount of tissue. In fact, if tissues are to be welded, energy has to hit a small amount of tissue to evaporate the water and denaturate the proteins. The denaturation creates a clot of coagulated proteins, and this produces the weld. Bipolar low-voltage coagulation delivers less highly focused energy, so that welding capacities are lower. When we attempted to solve this problem by increasing the amount of energy, carbonization and destruction of tissue occurred.

In conclusion, low-voltage bipolar coagulation is useless for welding tissues.

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