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A DEVICE FOR THE MEASUREMENT OF TENSION IN LARGE SURGICAL SUTURES

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ABSTRACT

A system for the measurement of suture tension in surgical operations has been developed.

The tension is deduced by the measurement of the force per unit length necessary to bring into contact the two lips of the cut.

A resistive strain-gauge transducer has been used to convert forces into electrical signals.

To have a measurement system suitable for sensitivity and range, a transformer of strain has been used. The transformer consists in a curved lamina at the end points of which the forces are applied.

Results are reported.

1. - INTRODUCTION

During surgical operations involving the cutting and the consequent suture of large muscular fasciae in abdominal region, the possibility of performing the measurement of the tension between the opposed lips is found very useful.

Tension is defined in the usual way as the force per unit lenth necessary to bring into contact the two lips of the cut.

Here is described a system for the measurement of suture tension by means of a transducer that converts the forces into electrical signals.

The system essentially operates as follows: two metallic plates are fixed on each border of the cut before the final suture and are then brought into contact; one measures the total force acting on the plates and consequently one obtains the tension acting on the suture.

2. - THE TRANSDUCER SYSTEM

For our purpose a resistive strain-gauge transducer has been chosen.

A strain-gauge is sticked on a metallic lamina: when a force is applied, the deformation of the lamina modifies the resistance of the gauge and an electrical signal can be related to the applied force.

In a first approach to the problem, one has to take into consideration that the forces to be measured range from about 1 to about 100 N.

The measurement system must so be sufficiently sensitive and sufficiently strong, without loss of handling.

Considering a flat lamina and applying Hooke's law, the needed thickness for having a significant variation of resistance is too low to be easily handled. For example in a bronze lamina of 10 mm length, for a force approximately of 100 N the thickness resulting to have a $\Delta R/R_0 \cong 0.01$ is $\sim 10^{-2}$ mm.

A transformer of strain has so been taken into consideration.

For a curved lamina as shown in fig.1, the relation between force diverging the end points and relative strain is $^{(1)}$:

$$F = EJA\epsilon^{*}/r^{2} \qquad (1)$$

where E is the modulus of elasticity of the material, J the moment of inertia of the section, r the bending radius, A a geometrical factor and $\epsilon^{*} = \Delta L/L_0$, where L_0 is the span of the arch and ΔL is its elongation.

The value of ϵ^{*} is related to the relative strain ϵ felt by the gauge at the top of the lamina, by the relation:

$$\epsilon^{*} = \mu\,\epsilon \qquad (2)$$

where μ is the transformation ratio given approximately by:

$$\mu = r/s\ AB \qquad (3)$$

where s is the lamina thickness and B a geometrical factor. The factors A and B depend from the angle α (fig.1) as follows:

$$A = \frac{\alpha \sin\alpha}{\alpha^2/2 + \alpha \sin 2\alpha/4 - \sin^2\alpha} \qquad (4)$$

$$B = (\sin\alpha - \alpha)/\alpha \qquad (5)$$

With a suitable choice of the geometry one can obtain a sufficient deformation of the gauge in order to have an electrical signal not too low. This signal is in fact related to the variation of the electrical resistance of the gauge that is proportional to strain:

$$\Delta R = k\ R_o \qquad (6)$$

where k is the gauge factor and R_o is the nominal resistance of the gauge.

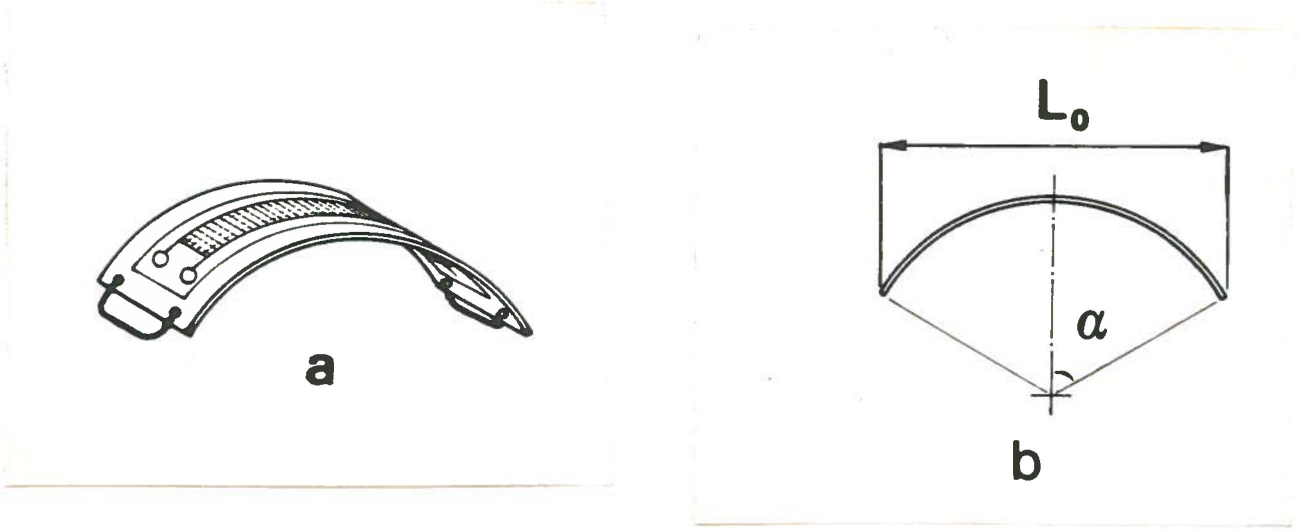

Fig. 1a) Curved lamina utilized with two strain-gauges sticked on external and internal side.
b) Cross section of the lamina: L_o is the span of the arch and 2α the corresponding angle at the center.

TABLE 1

Nominal resistance	350 Ω
Gauge factor	2.1
Maximum strain	9×10^4 μm/m
Width	6.0 mm
Length	13.4 mm

3. - EXPERIMENTAL

On the basis of the previous considerations a curved lamina with the following dimensions has been prepared:

$\alpha = 60°$
$L_o = 22$ mm
$a = 10$ mm

The dimension a is the lamina width.

Strain-gauges HBM LY 41, fully embedded in polymide film, with the characteristics and dimensions described in tab.1 are utilized.

In a first approximation, assuming for the gauge a maximum strain of 5×10^4 μm/m for an applied force of ~ 100 N, one determines a thickness of 0.15 mm for a bronze lamina.

It is well known that a strain-gauge is very sensitive to thermal effects, especially because of the thermal expansion of the element on which the gauge is sticked. So, if during the mechanical loading a thermal expansion occurs, the relation between the applied strain ϵ and the relative change of resistance becomes:

$$R/R_o = k\,(\epsilon + \epsilon') \qquad (7)$$

where k is the gauge factor, ϵ is the strain from mechanical loading and ϵ' is the undesired strain due to thermal expansion.

The thermal strain has obviously the same sign for all gauges sticked on the same lamina.

The mechanical load gives, for the curved lamina utilized, negative strain (compressive) on the external side and positive (tensile) on the internal side.

The temperature compensation, as will be shown below, can be reached placing a gauge on each side of the lamina. In fact for the ΔR measurement a Wheastone bridge is used, two arms of which are constituted by the two gauges and the other two by fixed resistors of value approximately equal to strain-gauge nominal resistance R_o (= 350 Ω).

If V_o is the voltage supplied to the bridge and ΔR_a and ΔR_b are the resistance variation of the two gauges, the output voltage measured is given by:

$$V = V_o(\Delta R_a - \Delta R_b)/4R_o \qquad (8)$$

that is:

$$V = V_o k\ (\epsilon_a + \epsilon'_a) - (-\epsilon_b + \epsilon'_b)\ /4 = V_o k(\epsilon_a + \epsilon_b)/4 \qquad (9)$$

One observes immediately that the output voltage results indipendent from the strain due to thermal expansion.

The bridge has been supplied with a 18 V constant tension and the output signal was connected to a voltmeter with a digital display. Moreover the circuit has been equipped with a balancing potentiometer which allows to set the output to zero for non loading state.

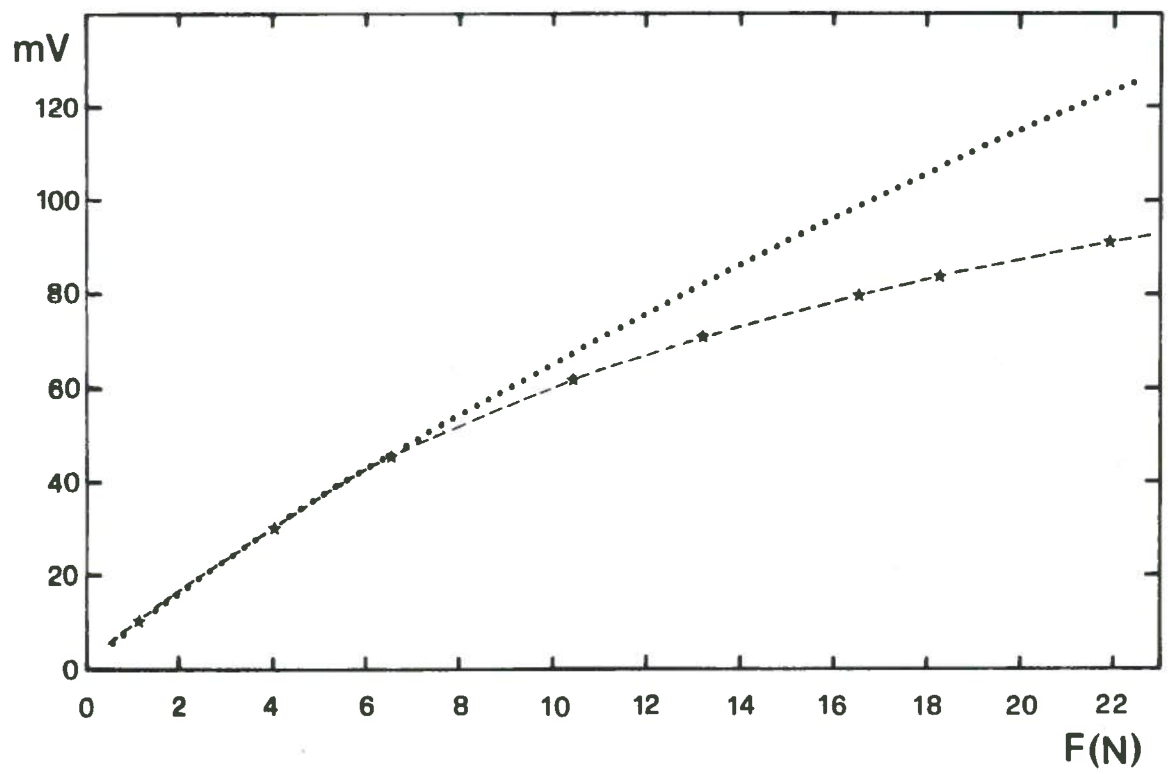

Fig. 2 Output voltage response as a function of the applied force. The dashed line represents the interpolation between the experimental points indicated by stars. The dotted line represents the calculated values.

For the calibration of the system the output voltage has been measured as a function of different loading weights applied to the transducer and the results are represented in fig. 2.

The non linearity of the response is attributable essentially to the particular shape of the lamina. In fact the analytical dependence of the output voltage from the applied force, obtained from the previous relation, is:

$$V = V_o k r^2 F/2EJA\mu \qquad (10)$$

where the proportionality factor between V and F is not a constant, because of the change of the geometric shape of the lamina when submitted to a force.

In fig. 2 the calculated values for the output voltage are also reported as a function of F; one can observe that this curve reproduces satisfactorily the behaviour of the experimental one only for little applied forces. The differences between the calculated and the measured values of the output voltage at higher applied forces are due to the difficulty of evaluation of a certain number of geometrical parameters and to the approximations made.

A series of repeated tests has shown the very good reproducibility of response of the system; successive measurements of the same weight after different intermediate loading conditions have given identical results within 0.5%.

The measurement of the tension between the opposed lips of the suture is performed in the following way: each border of the cut in the muscular fasciae is compressed between a device like that sketched in fig. 3. The device acts as a stiffener of the border and if its length is nearly equal to the suture is simply given by the forces necessary to bring the two bordures into contact.

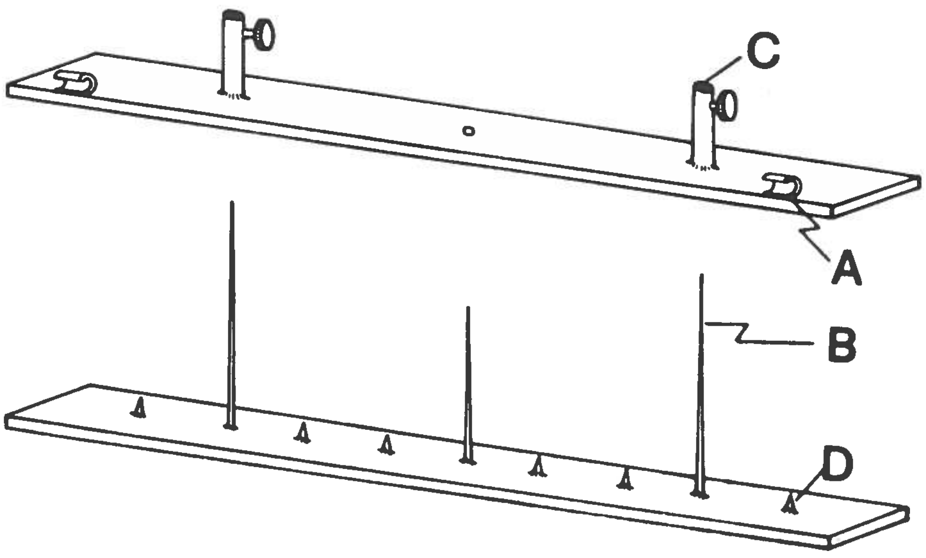

Fig. 3 Device utilized to apply the transducers to the borders of the cut. A) Hooks for transducer fixing. B) Long needless to be passed through muscular tissue and to be locked in the corresponding holes C. D) Short needles located at both the internal sides of the plates to better grapple muscular tissue.

To measure these forces the two borders are brought into contact by hand and then two transducers of the type described before with comparable behaviour are applied using the suitable hooks on the plates. Releasing the hand the only force acting on the opposite plates to bring them into contact is exerted by the transducers so that the electrical signals give, by comparison with the calibration curve, the forces acting on the suture. The tension is immediately obtained dividing by the cut lenght.

The electronic apparatus for the connection of the outputs coming from the two transducers with a recorder is sketched in fig. 4.

Three amplifier stages have been utilized. The first, A_1, is a pre-stage of amplification with high input impedence and has the function to connect the bridge with the amplifier, reducing the interference on the resistance measurement. The following stage of amplification, A_2, provided with the gain adjustment through a course gain switch and a fine potentiometer, allows the control of the recorder bias level. The third stage is a buffer with low output impedence which allows the maximum signal transfer.

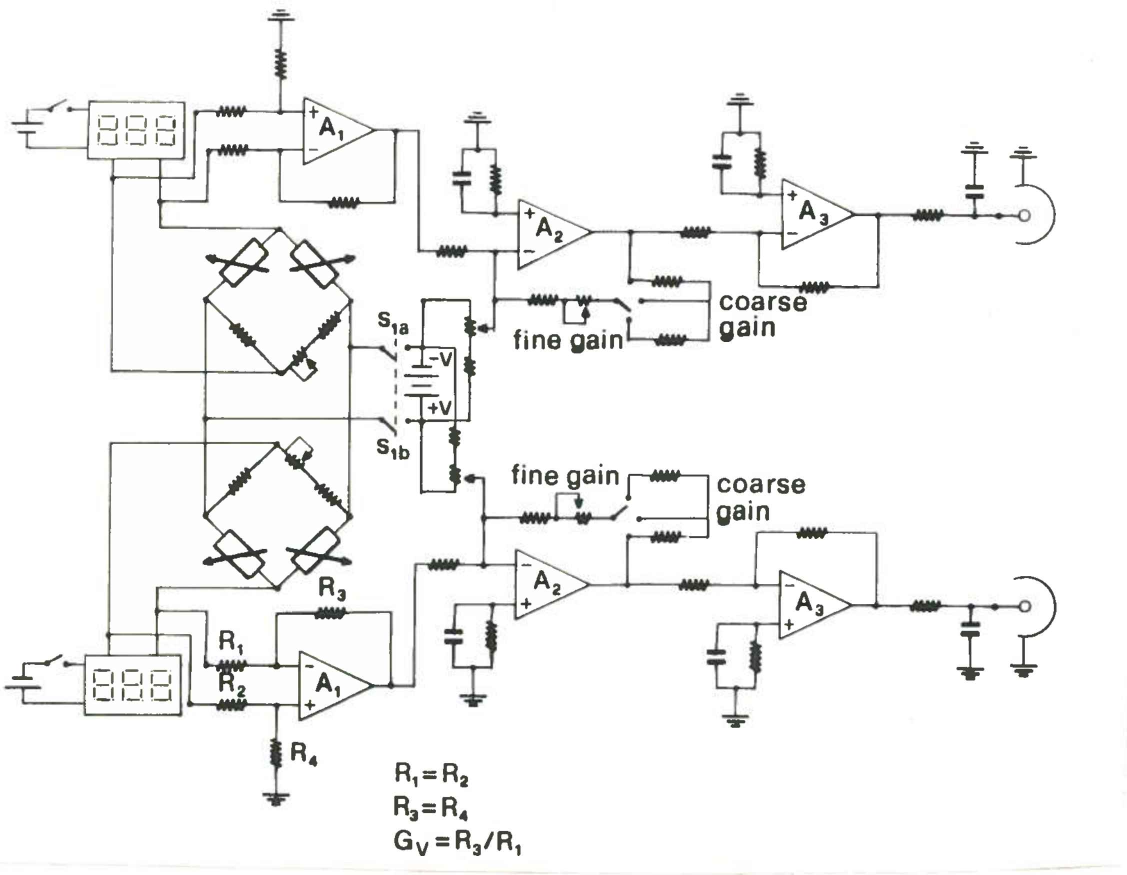

Fig. 4 Schema of the Wheatstone bridge circuits and of the amplification apparatus.

 = active strain-gauge.

4. - CONCLUSIONS

The simple device here described is now in common use at the Istituto di Patologia Speciale Chirurgica I dell'Università degli Studi di Milano.

The measurements are simple and reliable and the clinical results seem interesting(2,3).

REFERENCES

(1) R.Kautsch; Messtechnische Briefe, Darmstadt, 3, 56-57 (1968)
(2) R.Rossi, G.Trivellini, G.Zanella, P.G.Danelli, G.B.Galloni, N.Molho, M.C.Cantone; Chir.-Arch. Trim., 5, 373-376 (1981)
(3) G.Trivellini, P.G.Danelli, D.Pratolongo, C.Gatti, N.Molho, M.C.Cantone; Minerva Medica, 75, 36, 2083-2086 (1984)