Sternal Closure Using Semirigid Fixation With Thermoreactive Clips

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Sternal wire fixation was first used to close a median sternotomy by Milton in 1897 [1] and was later popularized by Julian and colleagues in 1957 [2]. Sternotomy represents the standard approach to the heart and great vessels in most cardiothoracic procedures. Closure of this incision is simple; however, healing complications such as dehiscence, osteomyelitis, mediastinitis, and superficial wound infection or fistula may occur. We believe that semirigid fixation with thermoreactive clips (nickel-titanium) may be superior to wire fixation in sternal closure, and describe our technique below.

Technique

NITINOL (an acronym for Nickel Titanium Naval Ordnance Laboratory) belongs to a family of intermetallic materials that contain a nearly equal mixture of nickel (55 wt %) and titanium. Nitinol exhibits unusual behavior characterized by shape memory and superelasticity.

Shape memory describes the process of restoring the original shape of a plastically deformed sample by heating. This is a result of a crystalline phase change known as thermoelastic martensitic transformation. Martensite is easily deformed by de-twinning. Heating converts the material into its high strength and austenitic condition. Shape memory effect is repeatable and can typically result in strain recovery of up to 8%.

With regard to superelasticity, martensite in Nitinol can be stress induced if stress is applied in the temperature range above austenite finish temperature. Because austenite is the stable phase at this temperature under no-load conditions, the material springs back to its original shape when stress is removed.

Nitinol alloys contain more nickel than do stainless steels. However, because Nitinol is metallurgically an intermetallic compound and not an alloy, the bonding force of nickel to titanium is much stronger in Nitinol than in alloy stainless steel components. Polarization testing in Hank’s solution has repeatedly shown that Nitinol is chemically more stable, less corrosive, and more biocompatible than stainless steel.

Nitinol is nonferromagnetic and produces fewer artifacts than does stainless steel during magnetic resonance imaging.

The Nitimplant clips are made of Nitinol alloy (Nitium Research SRL, Napoli, Italy), with a special shape for sternal closure (Fig 1). The transformation of Nitinol from austenite into martensite (cooling) and the reverse cycle from martensite into austenite (heating) does not occur at the same temperature. This process in Nitimplant clips occur at the following temperatures: temperature manipulation less than 8°C; temperature memory start action greater than 27°C; and austenite finish temperature 35°C. The clips are available in eight sizes ranging from 22.5 mm to 40 mm.

Sternal osteosynthesis is obtained with three Nitimplant clips located at the second, fifth, and sixth intercostal spaces. Electrocautery is used to create a tunnel through the intercostal space to set the clip, and attention
should be used to avoid harming the internal thoracic arteries. To get a landmark and to keep the sternum closed, loops are placed through intercostal spaces (Fig 2A); otherwise, two Backaus forceps may be used (Fig 2B). When the two parts of the sternum are put together, it is possible to measure the distance between intercostal spaces. This procedure is necessary to choose the clip size, which must be 7 to 8 mm smaller than the measured size (clip size range, 2.25 to 4 cm) (Fig 3). The clip is then cooled with ice and set on a special forceps with the loop toward the head of the patient. Cooling (< 5°C) makes the clip very malleable and easy to fit into the intercostal space. Finally, the clip is heated with warm water (Fig 4).

The time required to perform osteosynthesis with this new technique, after an initial learning curve of 5 consecutive cases, ranges between 3 and 5 minutes.

If a new sternotomy is required, clips can easily be removed by cooling and by using a special forceps, as the Nitimplant clip does not integrate in bone.

Comment

The above-mentioned technique was used in 100 consecutive patients at our institution. Patients and operative procedures were heterogeneous. No procedure-related complications occurred. No mechanical sternal dehiscence, aseptic sternal necrosis, infected sternal dehiscence, sternal-related hemorrhage, superficial wound infection or fistula and death (mediastinitis) were reported. This technique has several advantages. It allows semi-
rigid compression, with better and more physiologic sternal stability, as opposed to the rigid compression of the steel wire. These clips are thicker than steel wires and confer a lower risk of bone cutting. The above advantages contribute to minimize the risk of dehiscence in comparison with conventional wire. Other advantages of this technique are as follows: (1) Nitinol has a higher biocompatibility than that of steel; (2) Nitinol is fast and easy to implant, as well as to remove (Nitimplant clips do not integrate into bone); (3) this technique is relatively non-invasive; (4) the risk of bleeding is less than with conventional wires; and (5) Nitinol is a nonferromagnetic alloy, which ensures nuclear magnetic resonance feasibility. However, it is not possible to use this technique when the distance between intercostal spaces exceeds the size of clips that are commercially available (ie, 22.5 mm to 40 mm).

In summary, we believe that this is a safe, easy, and efficient technique for closure of sternotomy incisions.

References