THE SLIDING STAPLE-SPLINT
PROFESSOR JACQUES BORRELLY

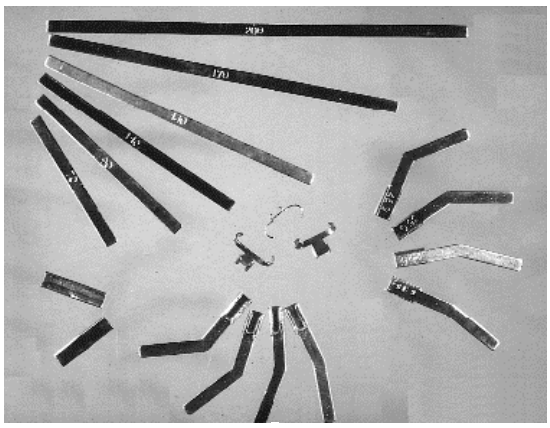


fig. 1 : implants

A strong, yet malleable, osteosynthetic implants, custom-made and in an extemporaneous way by assembling its components, easily implantable (6), constitutes the ideal means for stabilizing the chest wall when it is dislocated following an accidental trauma, or during a corrective osteochrondroplasty for a thoracic deformity. At that moment, the implnats are used as an orthosis.

Material of this type is also the best support for a plate covering the breach produced by an extensive thoracic tumour chest wall resection. In this instance, the implants are used as an isolated prosthesis or as the framework of a composite prosthesis.

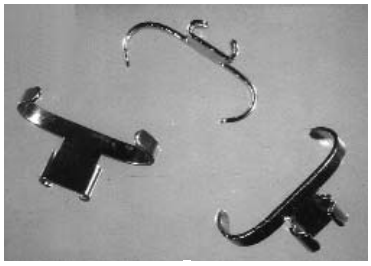


Fig. 2: staple

The sliding staple-splint may be used in the three main fields of chest wall surgery:

• traumatology (closed and even open traumas),
•orthopædic and plastic surgery of thoracic deformities (either simple or complex),
•cancerology in chest wall tumour resections.
The sliding staple-splint may also be used for sternal application in primary cardiac surgery and in the treatment of septical sternites.
The sliding staple-splint may be used in any "transcostal" thoracotomy.

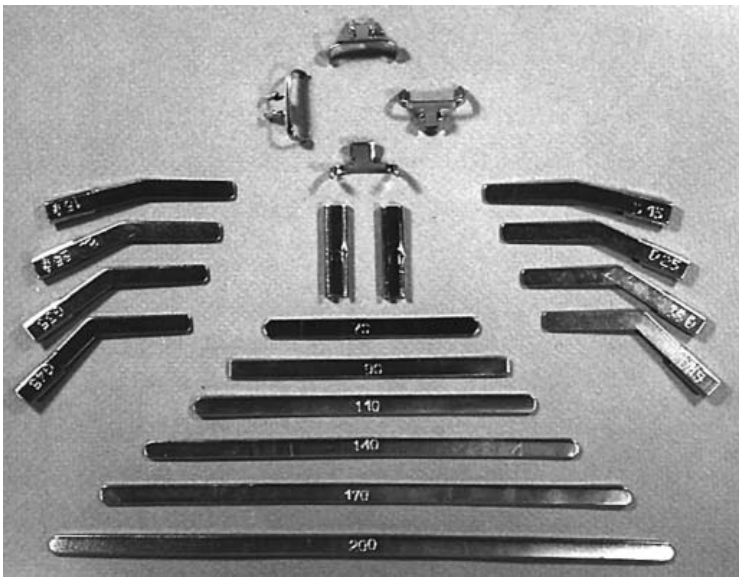


Fig. 3: The implants

The staple-splint is formed by an assembly of basic elements: splints, staples, and angled and straight connectors.

Assembly is based upon the crimped slide-tube principle. The sliding part of the staple or connector can assimilated with a female part, whereas the splint or the other part of angled connector is the male part.

The staples are all identical. Each staple has a slide-tube that will be slid onto a splint, or onto the male part of an angled connector.

Apart from the slide-tube, the staple possesses two clamps that are crimped to a rib or cartilage.

The straight splints come in lengths from 70 to 110mm (in increments of 20mm) and from 110 to 200mm (in increments of 30mm).

The flexibility of the steel permits the bending of the curvature along the faces (coiling) and around the axis of torsion. Final modelling of the splint should be left until after the staples and any connectors have been placed and set. Elasticity restores the shape imprinted by the modelling.

The angled connectors can be separated into two groups, a group of right connectors and one of left connectors. As a matter of fact, the slide-tube, which takes up half the dorsal length of one of the two sides, must always have its opening pointing out so that it can eventually be unclamped after the material has been implanted into the chest.

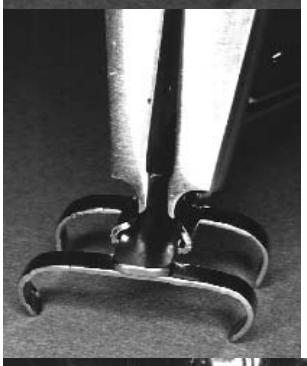
The angles range from 15° to 45° (in increments of 10°).
The straight connectors are slide-tubes and they serve as lengtheners which, for example, permit the creation of a 240mm splint from two splints: one 170mm and one 70mm.

Ancillary Material

Composed of three pairs of pliers and two bending pliers.

One pair of pliers for crimping the slide-tubes: with a highly reduced gear ratio, it is used to crimp the slide-tubes or the straight or angled connectors onto the splints.

One pair of pliers for releasing the slide-tubes: its thin jaws may be inserted into the opening of the slide-tube. The slide-tubes must always be opposite the bone on which the splint is most often applied: the exterior; in exceptional cases, it may be the interior of the chest if the staple-splint has been applied on the interior.



One pair of pliers for costal stapling: its jaws are slightly offset and have a groove that guides the staple clamps during clamping.

Bending pliers are used for anatomical modelling of splints and connectors. It is essential that the staple support (splint or connector) be accurately parallel to the rib or cartilage in the anchoring zone.

General principles and directions for using the material

Each staple-splint can be arranged and assembled completely before its implantation.
Using the staple-splint as an orthosis in traumatology, as well as using it as prosthesis in cancerology, are the cases most often seen.
Before implantation, only one extremity should be assembled. This is the case for correcting thoracic deformities when the material passes behind the sterno-chondro-costal plastron halfway through its course. The staples, and sometimes the second angled connector, are placed and assembled on the second side, only after application of the staple-splint on the first side.

Fig. 8: Arrangement of a 140mm staple-splint with two 45° angled connectors and four staples

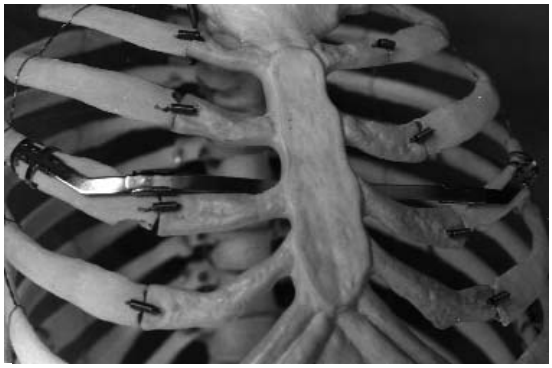


Fig. 9: Implantation in the thorax

Costal anchoring

The anchoring of each extremity of a staple-splint on a rib, more rarely on costal cartilage, even more exceptionally on a transverse apophysis or the clavicle, should always be done with two juxtaposed staples.
The splint must be parallel to the structure on which it is anchored, making it important to use the correct angled connectors and precisely modelled material in the anchorage zone.
Anchoring each staple should make a slight notch on the rib, often accompanied by a small cracking noise, thus ensuring a good setting.
Using a Jean-Louis Faure forceps can help to flatten the staple so that stapling occurs firmly around the rib.

Costal anchoring does not require the removal of the periosteum; the staple is applied directly to the rib and no special precaution is taken regarding the intercostal vasculo-nervous pedicle, either protected in its bony groove, or having been previously moved aside.

Fig. 10: Costal anchoring stapled twice with splint or angled connector parallel to the rib

Fig. 11: Endothoracic view

Ablation of the material

Easy to perform.

Removing the staples:
The costal staples are removed from the ribs by pulling forcefully, perpendicular to the surface of implantation.

Releasing the slide-tubes:
In the correction of funnel chests, it is important to locate the accessible side of the angled connectors' slide-tubes. This side corresponds to the one which was last joined.

Incidents and accidents

Crimping and releasing

It is important to verify that the crimping is correct before stapling the clamps on the ribs. It may be necessary to crimp many times with the forceps. Do no hesitate to remove an angled connector slide-tube and replace it with a different one that provides better parallelism to the costal anchoring area. Also, a staple which is not properly anchored must be replaced.
Unplanned removal is the result of an initial, inefficient crimping. It has very little effect, because the extremities of the pieces initially joined are smooth and physically inert.

Fracture of the material

Fractures can happen due to the effect of constraining forces, particularly when the staple-splint is used alone as a prosthesis between the two clavicles. This justifies the burial of the staple-splint in cement for Pr. Dahan (see Borrely's staple-splint and chest wall resection). Fractures can also occur as a result of micro-movements connected to respiration, repeated millions of times (9 million a year). This may occur after correction of a funnel chest, as well as after a chest wall resection. It is permissible at that time to remove the material quickly: ablation is very easy and requires no uncrimping.

Infection

Even if the initial operation was performed in a septic area, infection justifies the ablation of the material. After one month, the wall is still strong enough, even if the staple-splint has been used by itself.

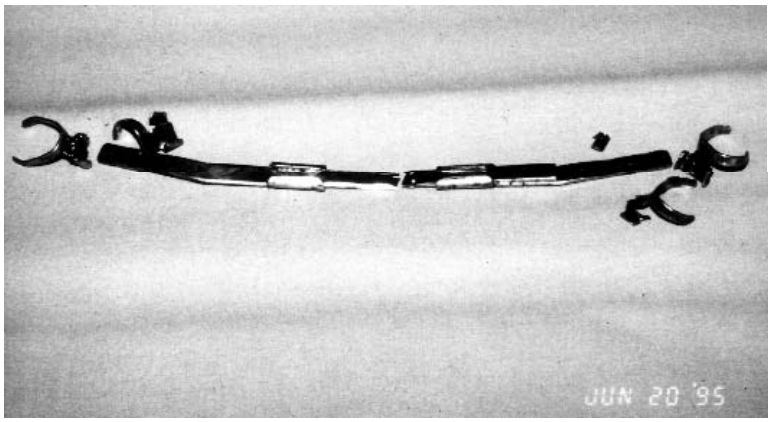


Fig. 12: Fracture after 90 million movements

SLIDING STAPLE-SPLINT AND STERNO-CHONDROMYOPLASTY WITH THE PARTICIPATION OF PR. R. JANCOVICI

If correction of thoracic deformities, of the type pectus excavatum, is a modelling plastic, it is necessary to make a stable internal retention; keeping it for a long period of time (from 1 to 3 years) insures a durable and definitive correction.

The objective of the correction of such a deformity is essentially æsthetic and psychological.
It is recommended to perform this correction only after the growth and after being assured of the absence of any underlying organic pathology, especially in Marfan's Syndrome. Modern imagery, and in particular three-dimensional reconstructions, allow one to estimate with high precision, the deformity to be corrected.

Positioning and approach

Fig. 13: Position with arms in cross-shape

The advised approach is the same for both sexes: the bilateral sub-mammary route, which is practically invisible in women. This approach uses the process recommended by Frank Martin in 1976 (7), in which a vast musculo-cutaneous segment is detached as a whole unit.

The patient is placed in a supine position, arms spread wide, with no hyper-abduction, with the trunk inclined toward the front, so that the sternal manubrium is horizontal. Hyper-abduction could retain the brachial plexus; we have already observed problems twice, fortunately reversible, in the secondary antero-external trunk area (musculo-cutaneous nerve).

Abduction of the superior limbs stretches and raises the Pectorals Major muscles.
At the end of the operation, the arms are placed down along side the body of the patient in order to reconstitute the Pectorals Major and Obliquus Abdominis Externus muscles, and the Rectus Abdominis sheath continuity.

On the cranial side, the continuity of pectoral muscles will be respected and preserved on the median line. The upper musculo-cutaneous segment will be turned as a whole unit after thorough hæmostasis of the vessels perforating the inter-costal spaces on both sides of the sternum; it may be raised up to the sternal manubrium.
On the caudal side, the thinner cutaneo-muscular cover, framed by the rectus abdominis muscle and obliquus abdominis externus muscles, is also detached from the plastron up to the inferior chondral extremity, when the xiphoid is entirely freed.

The sterno-chondral plastron is thus exposed, covered only by the Pectorals Minor muscles at its top and by the ventral strips of the Serratus Anterior muscles on its sides.

Plastron mobilization

Correction will be an horizontal sternotomy performed at the cranial end of the basin, and often, a longitudinal sternotomy of the caudal section.
Sometimes it is necessary to perform other horizontal sternotomies and resection of the xiphoid.
Sternum mobilization involves sub-perichondral and juxta-sternal chondrectomies; while more laterally, costotomies are performed on the edges of the basin and at the furthest part of the funnel, if it is asymmetrical.
During each of these gestures, be sure to pay attention to the inter-costal pedicles.
The pleuræ are systematically opened and drained. All of these gestures lead to a veritable, outspread, anterior, sterno-chondro-costal flail chest which one will stabilize most often by implanting two sliding staple-splints.

Plastron stabilization

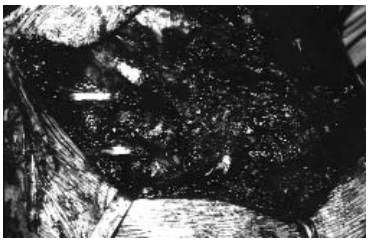


Fig. 14: Before closing, after correction with two sliding staple-splints

Each staple must be implanted beyond limits of the flail chest and will be placed behind the sternum. Two straight splints are inserted first, in order to estimate the correct length. The appropriate angled connectors are chosen, usually 45°, though sometimes 35°, and even 25°.

Each staple-splint is assembled on the first side with the adapted splint and the angled connector, as well as two final staples.
This hockey-stick-shaped staple-splint is inserted in staggered fashion behind the plastron. After anchoring the first side, the angled connector (if it has not been implanted) and the staples (if the connector is already set), are crimped on the other side before being anchored, strictly respecting the parallelism between the splint and the rib at the anchoring level. Sometimes, it is necessary to change the angled connector.

If the funnel is symmetrical, the staple-splints are more often placed on the fourth and the fifth arch on each side.

Fig. 15: X-ray after correction of a symmetrical funnel chest

Concerning a pectus arcuatum, the staple-splint, placed facing the protusal part of the sternum, passes in front of the plastron, as in a carina chest correction.

Fig. 16: X-ray of profile after correction of the pectus arcuatum.

Fig. 17: X-ray of profile after correction of the pectus arcuatum.

If the funnel is highly asymmetrical, the lateral implantation is neither performed on the same arches, nor at the same distance from the middle; an asymmetrical setting corrects the asymmetrical deformity, such as in the

observation of Marfan's Syndrome that we are presenting.

The staple-splints are not implanted symmetrically. On the right, the staples are crimped on the third and fifth costal arches on the nipple line. On the left, the staples are crimped on the fifth and seventh costal arches on the anterior axillary line.

Fig. 18: Highly asymetrical funnel chest

Fig. 19: Cosmetic result.

Fig. 20: Pre-operative X-ray. Heart on the right.

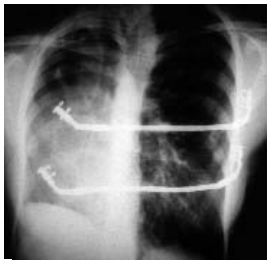


Fig. 21: Frontal post-operative X-ray

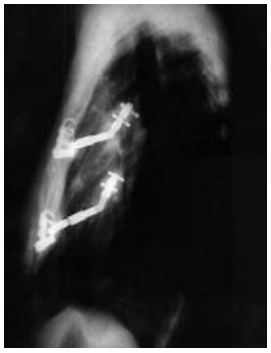


Fig. 22: Left profile post-operative X-ray

Closing

The sternum and the costal arches are most often repaired with reasorbable thread. Closing is performed with large Redon draining tubes placed in the detachment area, after lowering the two arms down along side the body.
The Rectus Abdominis muscles are re-implanted on the plastron and the Pectoralis Major-Obliquus Abdominis Externus unit is restored.

Sliding staple-splints in thoracic traumatology with the participation of Pr. G. Grosdidier

The minor part played by paradoxal respiration in the genesis of respiratory distress, in patients with serious closed chest trauma, together with progress made in the manipulation of increasingly sophisticated respirators and improvements in analgesic methods, might suggest that there is no longer a place for osteosynthesis.

The experience acquired during the past twenty years by a team of surgeons from Nancy proves the contrary. Apart from surgical indications based on serious visceral lesions, which require an osteosynthesis if justified by parietal damage, there is still a place for parietal thoracic surgery, particularly in direct and isolated chest traumas.
In sucking chest wounds, the use of the staple-splint, even though it concerns a prosthesis in a septic area, allows one to temporarily re-establish the situation when there is no obvious solution.

The surgical act

The surgical act, if required, must be global. In no way can it be limited to the wall without careful visceral verification.
One must also perform total pleural cleansing and drainage, whose ideal positioning would be located inside. Modelling by hand intra-thoracically renders reconstruction of the thoracic arch as anatomical as possible.

Topography estimation of the flail chest

This first step is essential because it effects the operative instructions and the approach chosen.
Palpation allows discovery of anterior lesions which do not appear on X-rays, especially if the patient is not ventilated. While the patient is being positioned, generally in supine position opposite of the flail chest situation, the pitch or thrust of the flail chest inside the thorax, gives a better impression of the focus of the bifocal injuries.

Positioning the patient and approaches

In opposition to the current tendency, which aims at diminishing the size of the incision and avoids the muscular sections, a wide approach is necessary in this case, cutting the shoulder girdle, the Latissimus Dorsi and the Serratus Anterior muscles.

It is necessary to verify the totality of the flail chest. Two approaches are used: the classic postero-lateral approach or the antero-lateral approach with the arm in abduction. The choice is determined in relation to the flail chest situation; the thoracotomy axis is at the centre of this situation.

Whatever the approach chosen, the possibility of extending it forward or backward must be available at every moment. Also, altering the orientation of the operating table has to be possible, so that the parietal plane on which osteosynthesis is practiced is as near as possible to horizontal.

Surgical technique

Opening the pleural cavity

An inter-costal incision at the heart of the flail chest, is an absolute necessity for verifying the integrity of the viscera and diaphragm.
However, it is advisable not to separate the ribs, so as not to aggravate the parietal damage; it is most often possible to make a complete inventory without inserting a Finocchietto retractor. Placing the hand in the chest provides the most precise inventory of fractures and dislocations, and this also allows the best anatomical modelling of the wall during the application of osteosynthetic material.
Pleural drains, usually two, are positioned before the parietal mending.

Applying the material

One must set the highest amount of fractures in order to obtain the best anatomical results and to suppress all mobility. However, we often forsake the superior focuses. It is better to synthesise all lateral focuses from the fourth to the eighth rib.

Strict chronological order must be respected. We start by setting and stabilizing the periphery and finish with the centre, using inter-costal space on both sides for visceral verification.

Each staple-splint is prepared and set. Staple-splints are used in two different ways, isolated or associated, and are adapted to the established damages.

Short staple-splints (70 or 90mm) are used for local osteosynthesis, either with Judet's staple, a pin or a plate; the elastic rigidity and the robustness of the orthosis may suffice to stabilize a distant hinge, particularly a chondro-costal disjunction.

Long staple-splints (200 - 170 - 140mm), eventually connected to angled connectors for their ventral portion, make up the struts, like the staple-splints described by F. Martin in 1976; lashed on both sides of the flail chest), they provide its central suspension with one or two intercalary staples. The application of the material must respect the general principles stated initially.

Fig. 23: Short and long sliding staple-splints

Closing

It is necessary to perfectly reconstruct the muscular wall, especially if the approach required a section of the two lateral muscles.
These muscles bruised by trauma, often ecchymotic and sometimes infiltrated with emphysema, require parietal drainage with two or three large Redon drains, which is very unusual in regular thoracic surgery.

Following the operation

Because of the stability it generates, a correct osteosynthesis has some important antalgesic qualities, however, it is recommended to perform, as in any thoracotomy, a high-quality analgesia, in order to achieve a good, diaphragmatic dynamic and to avoid broncho-pulmonary congestion and its consequences.
It is advised to use morphine injected by peridural or intravenously.
The objectives are extubation and weaning from ventilated assistance. A tracheotomy can be useful for a highly secreting patient; it is not a setback.

Surgical indications in closed trauma

Apart from thoracotomies for confirmed or very likely visceral lesions (i.e., bronchus rupture, massive hæmorrhage, pericardium rupture) which can benefit from an "exit" osteosynthesis if there is parietal damage along the chosen approach, the operative instructions, most likely to be parietal, are difficult to determine.

Surgery constitutes a therapeutic option, intermediary between necessary ventilating assistance (which is called for in seriously polytraumatic patients, a fortiori if (s)he is comatose and/or has a major pulmonary contusion), and the preservative treatment, the so-called "minor" means, including pleural drainage, analgesia, kinesitherapy, spontaneous ventilation assistance, broncho-aspirations, sometimes even tracheotomy.

The surgical option is considered a logical bet, allowing the avoidance or reduction of the duration of breathing assistance. The decision can be made by first intention during first two days, or more rarely, by second intention between the second and the fifth day after the failure of preservative treatment.

In no way, should we use osteosynthesis when controlled ventilation has failed (when the flail chest mobilizes in the case of a patient correctly ventilated, broncho-aspirated and drained).

After one week, there is no longer parietal indication.
The best indications are direct and isolated unilateral thoracic traumas of lateral or postero-lateral position, particularly if they are due to a fall from a high place. The thick, muscular wall protects the lung and absorbs the impact. Serious displacement of the costal fragments should prompt surgery in order to avoid impaction and a secondary restrictive syndrome.

Inversely, ventral thoracic traumas which are bilateral, concern a thin and fragile wall: the wall did not protect the seriously contused lungs; the resulting hypoxia requires a lengthy ventilatory assistance, and osteosynthesis is not a choice.
Cases of very old or uncooperative patients might also prompt surgery to shorten the duration of badly tolerated or accepted medical care. The setbacks of this surgical option are most often due to an unknown or under-evaluated pulmonary contusion.

Particular cases of thoracic wounds

Some thoracic wounds exhibiting a sucking chest wound, generate a substance loss of the thoracic wall, carrying away skin, sub-cutaneous cellular tissue, muscles and parts of the chest. Any attempt at crude closing is impossible, so one must call upon osteosynthetic methods and upon plastic surgery.
These lesions are often ballistic (i.e., buckshot); they are also seen in war situations or when the collapse of somethig involves projection of concrete, wood, metal, etc.

In all of those circumstances, after exploration of the thoracic cavity in order to treat possible visceral lesions, parietal reconstitution may be performed by an osteosynthesis with staple-splints; the latter requires an armature for the covering, which will use either an implant such as a Gortex plate implant or a myoplasty.

Two observations

Observation 1 — Mr. Do. C., 36 years old, suffered a car accident at noon on 3 December 1986 while driving (left-side impact; no seat belt). He exhibited a left, postero-lateral, chest depression extending from the third to the eleventh rib, with bilateral pneumo-thorax and left diaphragmatic rupture, as well as a pelvic fracture.
He arrived ventilated, and was operated on the same evening, using a large, left, postero-lateral access. The diaphragmatic breach, which ran from the apex of the heart in front of the aorta and down behind it, was repaired and the viscera restored (colon and stomach being put back into the abdomen). Two short splints were placed on each of the sixth and seventh arches, and three long splints were used for the eighth, ninth and tenth ribs.
The patient was extubated on the following day, 4 December 1986, and exited for convalescence on 20 December 1986.

Fig. 24: Initial X-ray

Fig. 25: Post-operative frontal X-ray

Fig. 26: Post-operative profile X-ray

Observation 2 — Mr. Ve. M., 43 years old, suffered an accident at work on 22 January 1986, his chest and right shoulder being crushed between a truck and a wall.
He exhibited open crushing of the axillary hollow with a shattered scapula, acromio-clavicular dislocation, elongation of the brachial plexus and right antero-lateral depression. Hemorrhagic shock made it necessary to infuse 25 units of red blood cells and 13 units of plasma over the first 24 hours. The wound was dressed on the same day, the right chest cavity was drained, and atypical resection of the superior lobe was performed. Seven rib arches were osteosynthesized with short or intermediate-length splints; one short splint was placed inside the chest on the posterior arch of the sixth rib.
The patient was extubated on the following day (23 January 1986). Osteosynthesis was applied to the acromio-clavicular dislocation on 3 February 1986 and he exited for convalescence on 15 February 1986.
The only after-effect was sub-scapular and circumflex nerve deficit.

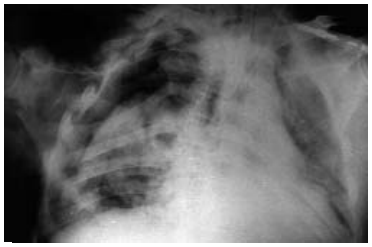


Fig. 27: Initial X-ray


Fig. 28: Post-operative frontal X-ray, day 1 (post-extubation)


Fig. 29: Post-operative frontal X-ray

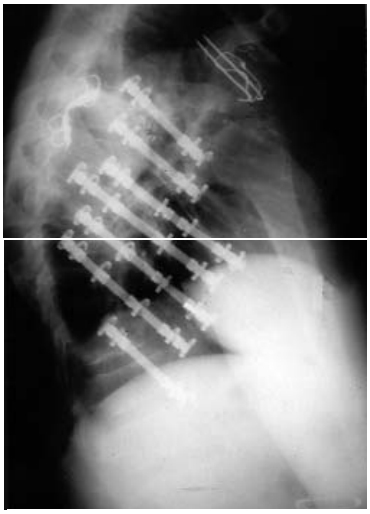


Fig. 30: Post-operative profile X-ray

Sliding staple-splint and chest wall resection with the participation of Pr. M. Dahan

If resection of a wall is very easy for a confirmed thoracic surgeon, it becomes more difficult for entire resection with a sufficient margin of safety.

As a matter of fact, we run into difficult problems of sacrificing certain “keystones” and their reconstitution.
For us, the reconstitution of the thoracic wall justifies the combined use of three materials: Goretex, sliding staples and methyl-metacrylate.

Three kinds of application
Three principal situations are interesting to consider:

Mending of an anterior costal or simple antero-lateral breach:
In this case, each rib is replaced by a staple-splint and a Goretex tent is stretched across like a big top circus tent. If the rigidity is strong enough, it is better to not use acrylic cement.

Mending of a more or less extended sternal resection:
In the second case, the setting of the staple-splints permits one not only to stretch the tent but also to fight against forces tending to impact the ribs forward. In all cases, we pour methyl-metacrylate on the tent in order to give this neo-sternum a consistency close to reality.

Mending of the sterno-clavicular resections:

In the last case, the contracting forces of the clavicles are such that the setting itself must be very strong. For this reason, we embody the splints in cement.
For esthetical reasons, and in order to avoid skin ulceration caused by the material, take care to bury the staples in the clavicles and to cover up the cement with a leftover piece of Goretex.
At the present time, the combination of these three materials (Goretex, sliding staple-splints and methyl-metacrylate) allows us to respond to all reconstruction situations involving resection of wall tumours.

Three observations

Observation 1: (Toulouse) A high sternal tumefaction, slightly painful and beating, but particularly murmuring, is discovered in 82 year-old Mrs. C. Léonie; this in addition to a goiter diagnosed a few years ago.
A CT scan confirms it as a sternal tumour, hyper-vascularised at the arteriography. A pre-operative embolization is performed in 1986. A metastasis of thyroid cancer is detected during surgery. A total thyrodectomy with resection of the sterno-clavicular plastron is performed on the patient.
Two staples are used for mending: one, inter-clavicular and the other laterally, between the second ribs.
In addition, the patient undergoes iratherapy. She is now 93 years old!

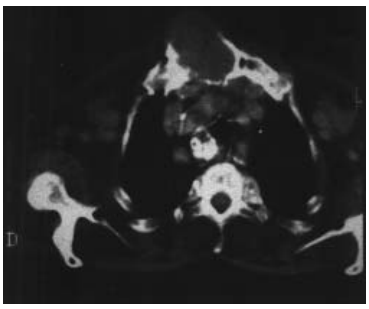


Fig. 31: CT scan of sternal tumour


Fig. 32: Hyper-vascularised sternal tumour


Fig. 33: Post-operative X-ray

Observation 2: (Toulouse) Mr. R. Michel, professional soccer player, 24 years old.
After a blow to his right shoulder, a tumour is discovered on the first rib. A needle biopsy classifies it as a Ewing's sarcoma.
Following chemio-therapic protocol, a clavicle resection is performed in 1994, involving the internal part of the sternum, the first rib and the pulmonary apex.

The clavicle is restored with a staple soaked in methyl-metacrylate, combined with a Goretex plate. The splint is impacted on the inside of the sternum. The operation is followed by radiotherapy. Unfortunately, the patient died two years later because of multiple metastasis. In the meantime, he was able to return to his job for more than one season without any functional difficulties.


Fig. 34: X-ray of tumour of the first rib

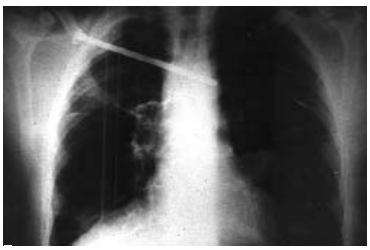


Fig. 35: Post-operative X-ray

Observation 3: (Nancy) Mrs. R. Simone, 60 years old. She exhibited sternal metastasis of thyroid carcinoma. She was treated by broad exeresis (22 January 1985), involving the manubrium, the median ends of both clavicles and the first two pairs of costal cartilage. Reconstruction consisted of only two staple-splints, the highest of the two being implanted on the clavicles.
The sliding staple-splint placed between the two second ribs fractured in June of 1995 (Fig. 12) and was removed without incident. The patient was doing well in June of 1997.

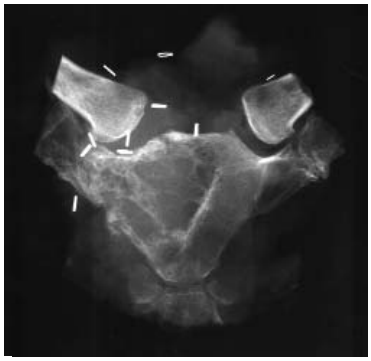


Fig. 36: Initial X-ray

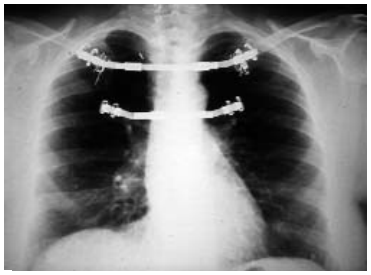


Fig. 37: Post-operative X-ray

Fig. 38: Post-operative scanographic slice

Sternal applications of the sliding staple-splint

The sliding staple-splint can be used in two apparently opposed circumstances concerning the sternum. In both circumstances, qualities of rigidity and stability are shown.
In primary cardiac surgery, the sliding staple-splint allows a stabilization of the plastron while maintaining, if needed, a consequent diastase between the two hemi-sternums.
Inversely, the sliding staple-splint allows a strong cooptation of the two sides of the sternotomy, either initially, in particular, in case of iterative sternotomies, or secondarily or more later, in case of infection and sceptical pseudarthrosis.

The sliding staple-splint in sternal distraction with the participation of Pr. B. Baehrel

Rare are the circumstances in which the closing of the sternotomy, after cardiac surgery under extracorporeal circulation, produces a degradation of the hæmo-dynamic constants.

We are presenting two observations of this type, where the use of sliding staple-splint allowed stable and impervious closing of the wall by pectoral myoplasty, while maintaining a 3cm diastasis between the two sides of the sternum with two or three sliding staple-splints.

The first observation from Reims (Pr. Baehrel) concerns a 66 year-old patient; (14 March 1989), although she had surgical treatment of an atrioventricular canal in 1979, it was impossible to close the sternotomy after the course of treatment for a sub-valvular aortic narrowing. Three staple-splints (two of 70mm and one of 90mm), each being lengthened with two angled connectors of 15, were implanted between the second, third and fifth costal arches with a 2cm-wide diastasis. The results were excellent and the material has never been removed.

The second observation from Nancy (Pr. Villemot) concerns a man, 38 years old, with a dilated cardiomyopathy to whom a left cardiac assistance of Novacor type was provided on 20 December 1996. A pericardial tamponade required another operation on 2 January 1997; closure of the sternotomy was impossible. Two 15cm staple-splints were implanted on the third and fifth costal arches, allowing a 3cm sternal diastasis. The patient was extubated eight days after surgery. The patient received a successful cardiac transplantation on 24 January 1997. The ablation of the sliding staple-splints presented no difficulties during the transplantation.

Fig. 39: X-ray eight days after implantation of two sliding staple-splints in distraction

Fig. 40: X-ray of the same patient after 27 days (five days after cardiac transplantation and ablation of the sliding staple-splints)

Sliding staple-splints and sternal cicatrisation with the participation of Pr. J. M. Wihlm

The sliding staple-splint may be used successfully for delicate treatment of sceptical sternites, and may even be used preventively to avoid pseudarthrosis of iterative sternotomies in cases of weak, obese or diabetic patients.

Two, or sometimes three, sliding staple-splints ensure an excellent stability and a strong cooptation between the two hemi-sternums. They are implanted on the second, third and fourth arches, level with the sternum, without detachment, each medial staple of each staple-splint being anchored level with the lateral edge of the sternum.

Consolidation may be acquired quickly and the material may be removed if suppuration persists for one or two months.

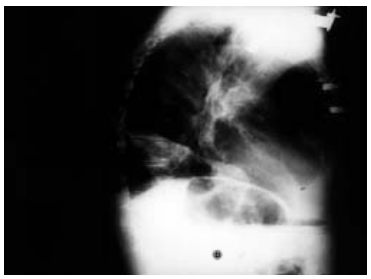


Fig. 41: Post-operative profile X-ray of two sliding staple-splints implanted on the third and fourth anterior costal arches for total and septic removal treatment of total sternotomy 13 days after resection-anastomosis of trachea.

Fig. 42: Cosmetic appearance of the same patient six months after surgery (Material is still in place)

Sliding staple-splint and “transcostal” thoracotomies
Pr. J. Borelly

The extraordinary ease of using the sliding staple-splint and its very high tolerance (after 10 previous years in classical indications), incited us to not hesitate in cutting the ribs at the very centre of their arch to make space, or more precisely, to temporarily give them more length.

There are some exceptional circum-stances for extracting massive tumours, such as a 2.5kg neurinoma in 1993; the sixth, seventh and eighth ribs on the right were sectioned to allow for tumoral exeresis and were immediately reconstituted (Fig.

Fig. 43: MRI of 2.5kg tumour of the right hemi thorax

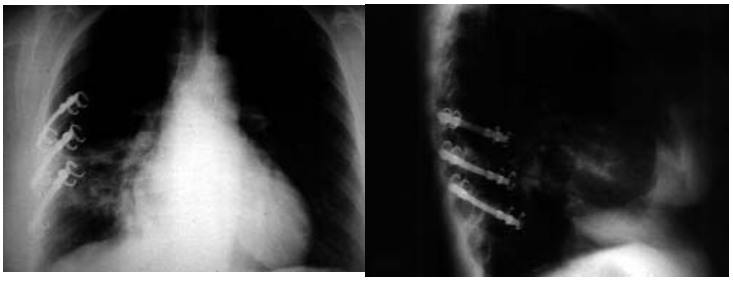


Fig. 44 and 45: X-rays after transection, frontal and profile, and mending of 6th, 7th and 8th costal arches.

There is a situation which is becoming routine for us (15 to 20% of thoracotomies in pulmonary surgery) which we call the high lateral thoracotomy or “transcostal” axillary.

The objectives of a high “transcostal” thoracotomy

The classic lateral thoracotomy9 without muscular section uses the fifth intercostal space, the sixth adjacent rib being one of the longest. If the pulmonary hilus is actually facing the fifth intercostal posterior space (postero-lateral approach), it is situated facing the fourth space at the central axillary level and also at the level of the more anterior third space, because of the costal obliquity.
The approach is relatively narrow, and pains from sprains or chondro-costal sub-luxation are often observed in the lateral area of sterno-chondral plastron.
Because we are convinced of the importance of this approach for the treatment of apico-ventral lesions, we have modified it, while specifying its indications.

Method

The incision made is higher than the classic lateral thoracotomy, with a section of the sub or sus-jacent rib, the mending is often performed easily with no after-effects.
Any intercostal separation has repercussions on adjacent costo-vertebral and chondro-costal ligaments and involves a stretching-deformation of the concerned ribs. This stretching is limited to the flexibility and the length of the ribs.
Using the fourth or, a fortiori, the third intercostal space, including the space between the much shorter ribs, the stretching is less. To work out this problem, we performed transversal sections (slightly oblique), either on the only inferior rib in the space, or on both sides with de-limitation of the intercostal space.
This allows a stretching of the opening’s limits, whose biconcave form becomes diamond-shaped, while the muscles and intercostal pedicles are not stretched. The mending of the incised rib(s) may be performed while closing.

Advantages
This approach makes the mediastinal plane less deep, which is appreciable for dissection of the superior vena cava dissection, or of its beginning branches on the right, and for the aortic arch or sheaf on the left.
This very high thoracotomy between non-diaphragmatic and not very mobile ribs generates much less post-operative pain.
Whereas, in the beginning, only the inferior rib was incised and repaired systematically, now the two adjacent ribs are sectioned in all cases. Total mending is only performed for partial exereses in the cases of elderly subjects or subjects with difficulty of breathing.

Results
61 thoracotomies: 26 on the right side and 35 on the left side. The third space is used 37 times, the fourth one 22 times, the fifth and the second two times each. Costal section is single 18 times, and double 43 times, with a chest wall resection of at least one rib eight times.

Mending with sliding staple-splints is performed in 51 cases: 34 times, it is total (one staple for each sectioned rib), and it is partial 17 times. The indications concerned 54 malignant and seven benign lesions. The exereses are 15 pneumonectomies (12 on the left, three on the right), 32 superior lobectomies (19 on the left, 13 on the right), and 11 parenchymatous exereses more reduced. We took this approach for the exereses of two posterior and superior right neurinomas of the cervico-thoracic defile. Finally, we used it once for a myoplasty of a right oeso-tracheo-pleural iatrogenic fistula of the cervico-thoracic junction.

2 observations

Observation n°1
Mr. D. Dario, 68 years old, 1 July 1994, has a left superior pleurolobectomy, enlarged at the wall at the level of the second, and at the level of the adjacent spaces by ancillary thoracotomy at the third space, with section of the third and fourth ribs. Ribs are repaired at the end of surgery.
It is an epithelioma T3 N0. Today, the patient is doing well.

Fig. 47 and 48: Profile and frontal X-rays, high "transcostal" lateral thoracotomy, 3rd intercostal space.

Fig. 46: Post-operative thoracic scan, high "transcostal" axillary thoracotomy

Observation n°2
Mr. D. Maurice, 66 years old, 20 April 1994, has an atypical resection of the superior right lobe. Previously, the patient had had surgery for an epithelioma of the middle lobe T2 N0 in December of 1990, by right postero-lateral approach. The axillar thoracotomy passed through the third intercostal space with section and mending of the third and fourth ribs.

Fig. 51: Two scars from the thoracotomy

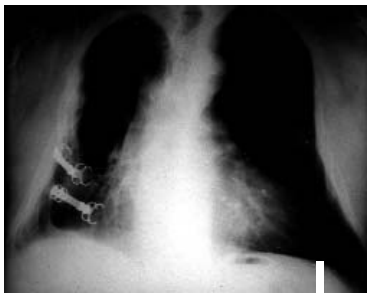


Fig. 49: Post-operative frontal X-ray

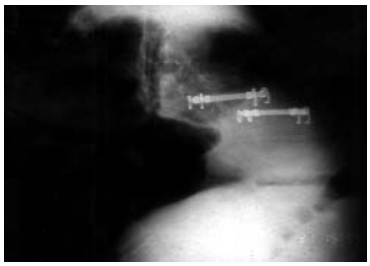
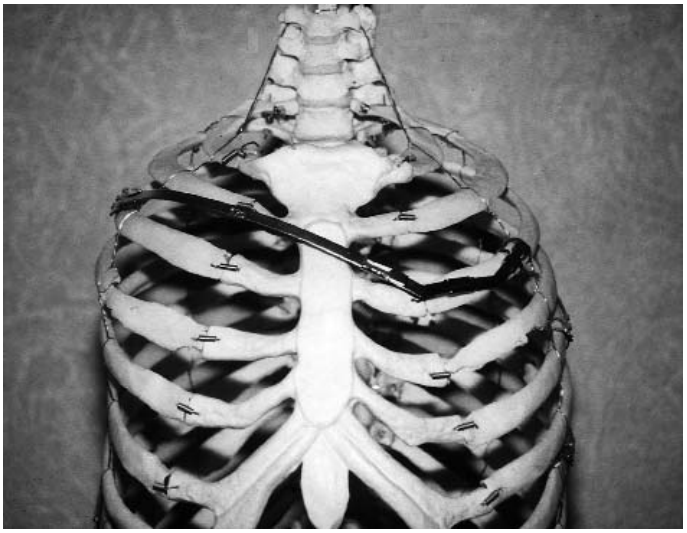


Fig. 50: Post-operative profile X-ray

Conclusion
The costal transection seems to us to be a soothing action, very useful when using a high space, all the more necessary when the ribs have lost their elasticity. These indications could probably be extended to the aortic arch and cardiac surgery.

General conclusion

The sliding staple-splint seems to be able to secure the stability of the thoracic wall anywhere it is placed. Some fairly modest, experienced constraints, and a rapidly acquired solidity of the thoracic wall, justify the use of such material in all circumstances, including in a septical area. Sternal applications, as much in coaptation as in distraction, should provide simple therapeutic solutions to particularly serious and complex problems.



References for Borrelly’s staple

Staples 37.700.00

Splints

Reference	Long.
37.702.07	7 cm
37.702.09	9 cm
37.702.11	11 cm
37.702.14	14 cm
37.702.17	17 cm
37.702.20	20 cm

Connectors
37.701.00: Straight sliding connector
Angled sliding connectors

Left	Angle	Right	Angle
37.703.15	15°	37.70415	15°
37.703.25	25°	37.70425	25°
37.703.35	35°	37.70435	35°
37.703.45	45°	37.70445	45°

Ancillary

Reference	DESIGNATION
37.710.00	Forceps for crimping staples to ribs
37.710.10	Forceps for crimping staple-splints and connectors to splints and straight connectors
37.710.20	Forceps for uncrimping staple-splints and splint connectors and angled connectors
37.710.30	plate forceps

Bibliography

1 Borrelly J., Grosdidier G., Wack B.
“Traitement chirurgical de l’instabilité pariétale thoracique, par l’attelle-agrafe à glissières,” Rev. Cir. Orthop., 1985, 71, p. 241-250.

2 Borrelly J., Grosdidier G., Wack B.
“Notre expérience de 5 ans d’utilisation d’un nouveau matériel d’ostéosynthèse thoracique: l’attelle-agrafe à glissières (AAG),” Ann. Chir.: Chir. Thor. Cardio-vasc., 1985, 39, p. 465-470.

3 Borrelly J., Grosdidier G., Wack B., Boileau S., Skorintschnouk L.
“Place actuelle de l’ostéosynthèse dans le traitement des traumatismes thoraciques graves avec l’instabilité pariétale,” Chirurgie., 1987, 113, p. 419-426.

4 Borrelly J., Grosdidier G., Maestracci C.
“Exérèse élargie d’une tumeur métastatique pulsatile du manubrium sternal, reconstruction par attelle-agrafe à glissières,” Ann. Chir.: Chir. Thor. Cardio-vasc., 1987, 41, p. 498-502.

5 Eschapasse H., Gaillard J., Henry E., Vassalo B., Lacheheb M.
“Chest wall tumours: Surgical Management,” In: Major Challenges - International Trends in General Thoracic Surgery, 1987, W.B. Saunders Company, p. 292-309.

6 Katz J. L.
“Prosthetic and restorative materials for bone,” Biomaterials - Biogineering applied to materials for hard and soft tissue replacement, University of Washington Press. Edit., 1971, p. 79-103.

7 Martin, Frank.
“L’attelle-agrafe de Martin-Corvisier/The two staples strut,” Thèse Médicine Nancy, 1976.

8 Martin, Frédéric.
“Les déformations du plastron sterno-chondro-costal et leur traitement chirurgical chez l’adulte,” Thèse Médicine Nancy, 1990, 263 pages.

9 Noirclerc M., Dor V., Chauvin G., Kreitman P., Masselot R., Balenbois D., Hoyer J., Broussard M. “La thoracotomie latérale large sans section musculaire,” Ann. Chir.: Chir. Thor. Cardio-vasc., 1973, 12, p. 1881-1884.

10 Ravitch M. M.
“The operatvie treatment of pectus excavatum,” Ann. Surg., 1949, 129, p. 429-444.

11 Ravitch M. M.
“Pectus excavatum et pectus carinatus,” In: Congenital deformities of the chest wall and their oper-ative correction., W.B. Saunders Company, Philadelphia, London, Toronto, 1977 p. 78-232.