Diaphragmatic relaxation: Pathophysiological alterations and current possibilities of surgical repair

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Diaphragmatic relaxation is a pathology not frequently observed because it is generally oligosymptomatic.
The development of modern technology has induced an important contribution to the diagnosis and treatment of the disease which can find a possibility of restoration in surgery.
A 63-year-old patient with a light syndrome of respiration deficiency and an altered relaxed profile of the right cupola was subjected to surgical treatment with the technique of diaphragmatic plicature without any adverse implication during and after the operation. After a brief recovery, the patient was discharged and after 9 years he affirmed still absence of dyspnoea from limited labor and absence of respiration problems. The selected surgical technique for the restoration of the altered muscle is the diaphragmatic plicature without incision or excision of the altered part of the muscle. The preferable access way today is that of laparotomy which is devoid of problems of thoracotomy and generally it permits quite easily the restoration of all *diaphragmatic defects.*
Diaphragmatic plicature is a simple, effective and long-lasting intervention but we cannot determine the complete recovery of the normal contractile function of the muscle. There is no morbidity and mortality directly related to this technique, the latter incidentally associated with complications of general anesthesia.

KEY WORDS: Diaphragmatic relaxation, Plicate of the diaphragm.

Introduction

The function of the diaphragm is central in the respiratory dynamic. Every defect of its contractility compromises the effectiveness of the respiratory exchanges due to its deficient function as a pair of bellows.
Except for the diaphragmatic lesions that can follow an open or closed thoraco-abdominal trauma, there are other pathological conditions which can make inefficient either an hemi-or the entire diaphragm .
Nowadays surgery is advantaged by sophisticated diagnostic instruments and technological facilities which permit the restoration of any possible diaphragmatic defect, when clinically evident and meaningful, besides naturally the thorough physiopathological knowledge acquired thanks to the modern thoracic surgery.

Case report

A *63-year-old man* was admitted in the 1st Surgical Clinic of the University Hospital "SS. Annunziata" of Chieti in 1995 hospitalized because of a respiratory failure crisis. The patient was affected by dyspnoea, polypnoea on limited labor and presence of subcyanocis in the absence of evident cardiopathy, which was thereafter excluded by the cardiologists.
In the subsequent diagnostic process of the patient a static x-ray of the thorax demonstrated a significant and permanent elevation of the right hemi-diaphragm which projected in P-A projection at the level of the fourth intercostal space. The fluoroscopic study

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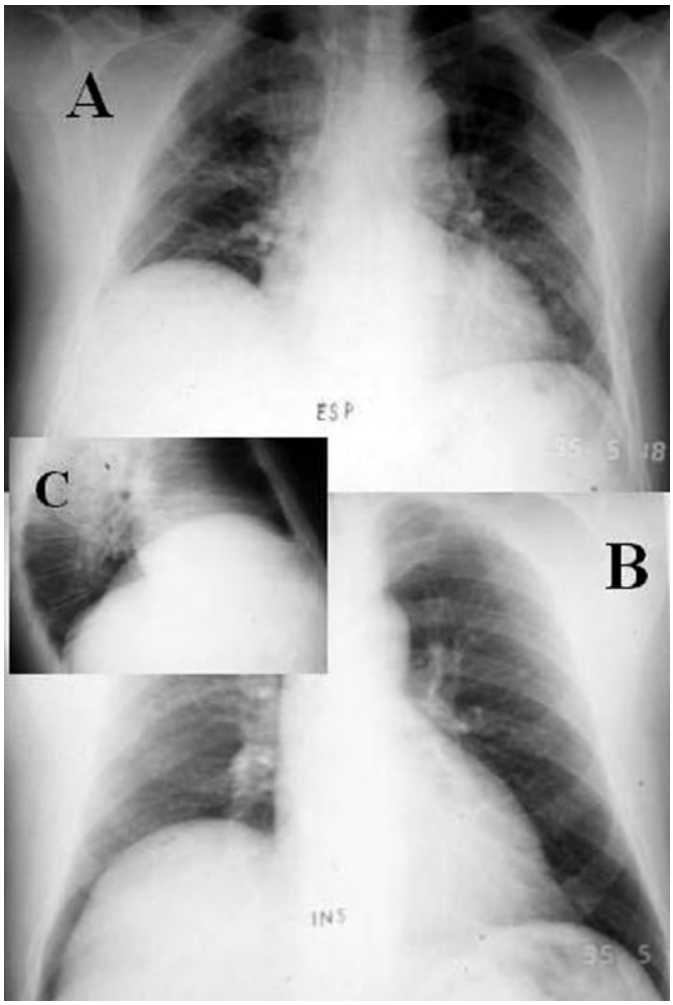

Fig. 1: Pre operative X-ray. Confronting inhalation and expiration both the raising of the right diaphragmatic dome (A) and the exaggerated widening of the right costo-phrenic sinus (B) become evidentel, without equivalent lowering of the dome, lowering of the dome, that remains high located (C).

demonstrated a clear symptom of Kienböck, while the functional respiratory tests gave a Current Volume of 450 cc, with respiratory frequency of 22/min, and reduced Inhaling and Expiratory volumes, and therefore of the Vital Capacity. Therefore the diagnosis of diaphragmatic relaxation without apparent cause become evident.

The patient was informed of the benign nature of his pathology, the therapeutic potentials, the potential evolution of the disease without surgical procedure and the possible complications connected to the treatment itself, recommending a reconstruction of at least the static function of the hemi-diaphragm by means of a doubling of it by folding. The patient accepted to proceed with the surgical intervention proposed.

Surgical intervention:

Through a sub-costal, bilateral laparotomy, prevalently extended on the right side, the liver cupola was exposed,

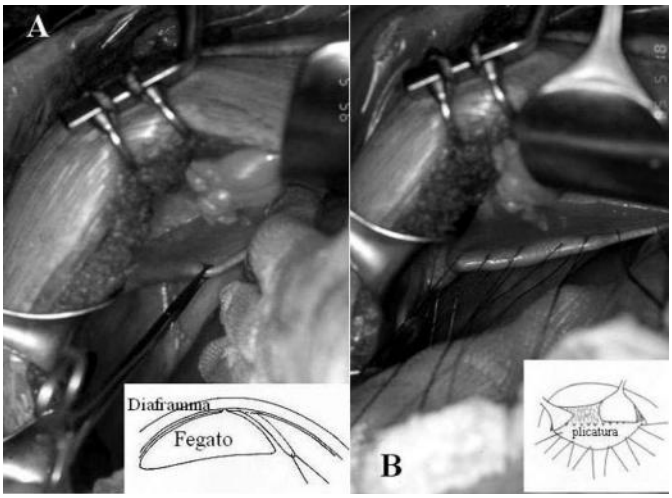

Fig. 2: The flail right hemi-diaphragmatic dome is grasped by a Babcock forceps (A), and e series of pulling stitches is placed across all its free margin, making a fold.

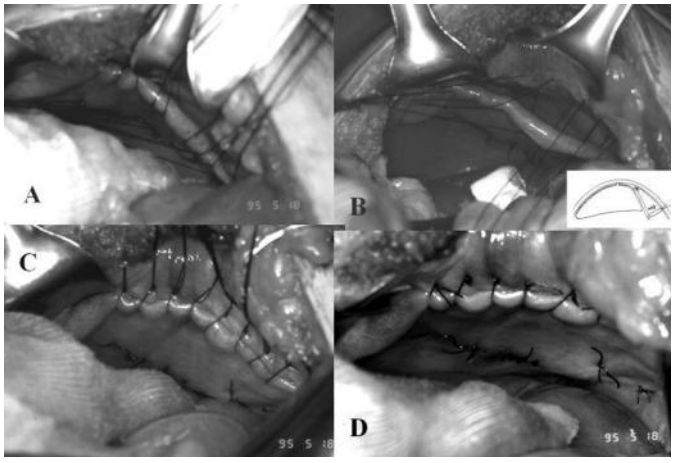

Fig. 3: At the base of the fold a series of U stitches are passed and knotted (A), to stabilize it. The anterior margin of the fold, is lifted and fixed to the anterior costal insertion of the diaphragm (B, C). The fold is finally fixed and at the lower aspect the U stitches are evident (D).

Fig. 4: View of the asymmetrical subcostal laparothomy.

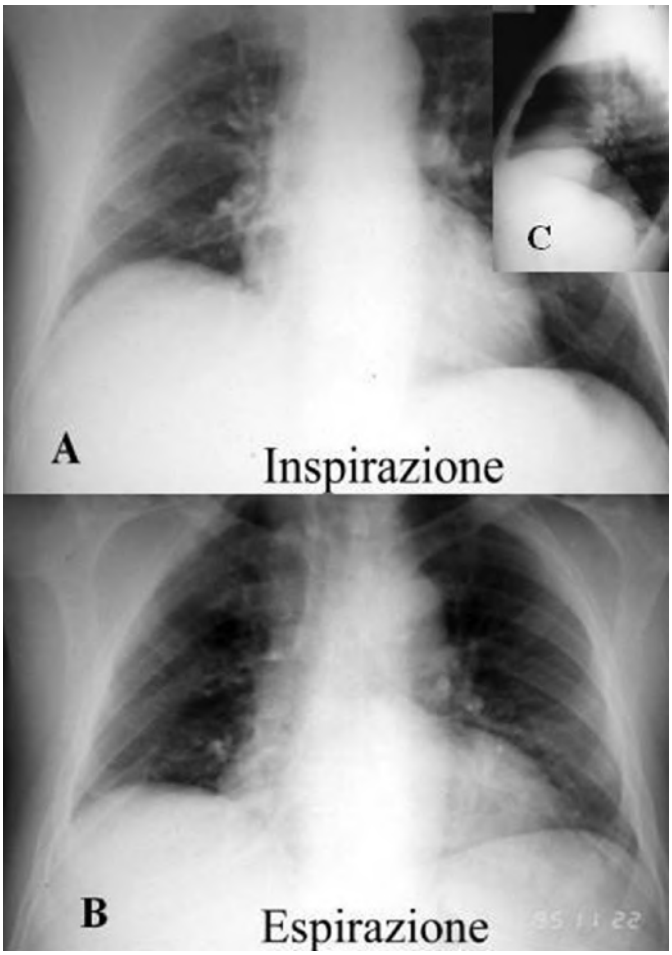

Fig. 5: Control of diaphragmatic motility after the consolidated healing. A, B: mild lowering of the right hemi-diaphragmatic dome, with lowering of the left one during inhalation. B: reduction of the costo-phrenic sinus at rest.

severing the sickle-shaped ligament up to the point where it joints to the sub-diaphragmatic inferior vena cava. The right diaphragmatic cupola, become thinner, is grasped by Babcock forceps, drawn downwards, paying attention not to include the overlying pleura and lung parenchyma. Naturally for the same purpose the applied traction was progressive and moderate. A series of successive, non-absorbable stitches are passed through the margin of diaphragmatic folding for all its length, pulling finally on the stitches, to elevate it from the basal dome (Fig. 2B). Thus, a series of U-shaped stitches is applied right at the basal margin of the diaphragmatic elevation, transfixed on both surfaces of the stretched fold, making stable and autonomous the diaphragmatic fold as regard of the remaining diaphragm (Fig. 3A). For this suture non-absorbable stitches of 1/0 or 2/0 caliber were used, with knots tightened on the lower, abdominal, side of the fold. It war thereafter bend forwards to duplicate the lower anterior diaphragmatic surface, and fixed by suture with the previous marginal non absorbable stitches, to the front costal insertions of the diaphragm fibers with a series of X-shaped knots (Fig. 3C-D).

Results

Postoperatively all the clinical and laboratory tests necessary for the evaluation of the outcome were carried out. Already a few days after the operation, the patient affirmed absence of dyspnoea and the Current Volume was increased to about 530 cc. The patient's follow up continues until today and the respiration conditions remain good after 9 years.
From the clinical point of view, lack of dyspnoea and absence of subcyanosis were constantly reconfirmed. The respiratory functional tests demonstrate a permanent improvement of the Current Volume, with a Tiffenau index of 74%, however without a return to the normal values. In the fluoroscopic study, a satisfactory post-operational mobility of the right side of the muscle was demonstrated and particularly a lack of paradox movements. Therefore a stabilization of the right diaphragm was obtained. The Spirometric examination showed that the vital capacity (VC) as well as the force of exhaled volume of air in 1 sec (FEV 1) was within the normal range.

Discussion

Under normal conditions the down movement of the diaphragmatic dome of 1,5 cm during the inhalation phase causes an augmentation of approximately 270 cc in the thoracic volume, whereas the exhalation – fundamentally passive and caused prevalently by muscular contraction of the abdominal wall – provokes a decrease of the same measure. Therefore, a decrease of 3 cm of the profound inhalation acts corresponds to an increase of over 700 cc of the thoracic capacity [1]. The air volume during normal respiration ranges between +270 cc and –270 cc for a complete 3 cm up and down movements of the diaphragma, moving a normal Current Volume of 540 cc, which is the one utilized in normal respiration. The diaphragmatic relaxation is characterized by a global lack of respiration movement of the affected part, and thus a defective Current Volume for every respiration act. The paradox movements of the Kienböck phenomenon make worse the respiratory defect, with effects analogous to those of the "flail chest". The parameters of normal respiration physiology are therefore deeply altered, not only because of Current Volume reduction, but also because of the lack of functional movements in the airways. Must be underlined however that the clinical defective respiratory presentation of the hemi-diaphragmatic relaxation is not absolutely well correlated to the extent of muscular defect. Patients with serious forms of the disease on a morphological and fluoroscopic level, may be asymptomatic, whereas patients with a limited extent of the disease may manifest symptoms. It is evident that this variety of clinical pictures makes the selection

of patients to undergo the surgical operation difficult. In fact, it is generally accepted that surgical treatment is indicated only in cases of evident simptomatology, especially if involving the thoracic organs or the abdominal ones, which are probably implicated in this pathologic condition. In the case of a symptomatology which lasts less than a year and is of neurological or infectious nature, a wait and see approach may be adopted, hoping for a nervous revitalization and re-innervation of the dome area. An 8-12 month interval is necessary for the recovery; this interval may reach or exceed 18 months [2].

The possible surgical methods for repairing the diaphragmatic defect may be of two kinds: the diaphragmatic doubling by folding and the incision followed by a suture of the type "double breasted" [2]. What must always precede is a complete liberation of the "relaxed" diaphragmatic cupola in all its extent except for the coronary area of the liver in cases of right diaphragmatic relaxation. The phrenic center in contact with the pericardium must be detached only when the selected access route is the thoracic one [2]. Among the possible surgical methods, the one selected in our experience was the method of diaphragmatic doubling by folding. Particularly important for the surgical intervention of the diaphragmatic relaxation restoration is to ensure the integrity of the phrenic nerve, a caution which is superfluous if the stable deficiency of the nerve is the real cause of the pathology. The preferable access route is the abdominal one. The thoracic route is unavailable if the liver itself is herniated in the thorax or if the relaxation concerns also the rear part of the dome.

Our choice was for the diaphragmatic doubling folding by means of a laparotomic access, which is devoid of the postoperative problems of thoracotomy. However, it permits quite easily the restoration of all diaphragmatic defects and, if needed, it permits also an inspection of the abdominal internal organs.

The direction of the diaphragmatic folding is selected according to the longer axis of the relaxation. The folding, therefore, may be transverse or front-rear, but the best results are accomplished with the transverse plicature.

In the application of stitches in U shape at the base of the plicature, we must warn against the possible perforation of pleura, which could be drawn down pulling the margin of the plicature itself as described. For this reason, a good coordination with the anesthetist can draw timely the attention to a possible provoked pneumothorax. To avoid this, it is necessary that the stitches should not tear the diaphragmatic plane, should be close one to another and taken with moderate thickness of the tissues.

If we are not certain of the diaphragmatic solidity, it is possible to reinforce it with a sheet of prosthetic material (a net of polyglactic or polyglycolic acid or polypropylene) or autoplastic tissues (fascia lata tendon). The heteroplastic materials less preferred are polypropylene nets because they create adhesions with adjacent tissues they come in contact with, in favour of the sheets of tetrafluoroethylene (permanent material) or absorbable polymer nets as polyglactic or polyglycolic acid, predisposed to hydrolytic destruction.

The rigidity attained in the right semi-diaphragm through plicature renders the paradox respiration movement far less effective, with reduction of the flail diaphragm and creating a strong supportive point for a better effectiveness of all the respiratory muscles, and naturally of those of the healthy hemi-diaphragm. The pulmonary volume during the last inhalation phase increases because the pressure applied on the lung by the abdominal content is inhibited [3].

The diaphragmatic plicature, in our experience, is a simple and quick surgical technique which can be applied without risks during operation even on infants and with favorable and long-lasting results [4].

This technique proved to be without morbidity or mortality and with a brief post-operational rehabilitation. Therefore, it's a safe, well-tolerated technique and permits a reduction in pulmonary compression of the affected side, a stabilization of the thoracic base and the mesothorax and a reinforcement of the respiration action of intercostal muscles and of the abdominal ones [5], through a rehabilitation of their tension state.

Conclusions

The purpose of surgical correction of the diaphragmatic relaxation is not that to improve the mobility of the affected diaphragm, but to reinforce and make stiff the diaphragmatic plane. Generally it retains limited mobility but the convexity is permanently reduced, thus improving the respiration function, eliminating the flail passive movements. In fact, even if it is not possible to recreate movement, which depends mainly on the presence of innerved muscles, there is an augmentation of the thickness and stiffness of the diaphragmatic layer which, this way, partly loses its passive retreat in the muscular abdominal thrusts, reducing the symptom of Kienböck.

Riassunto

La relaxatio diaframmatica è una patologia di non frequente osservazione anche perché in genere oligosintomatica. Lo sviluppo della tecnologia moderna ha apportato un'importante contributo alla diagnosi e al trattamento della patologia, che quindi ha nella chirurgia una possibilitá di riparazione.

Un paziente di 63 anni con sindrome di lieve isufficienza respiratoria e con un profilo diaframmatico della cupola destra alterato viene sottoposto al trattamento chirurgico con la tecnica della plicatura diaframmatica sen-

za complicanze intra e post-operatorie. Il paziente, dimesso dopo breve convalescenza, dichiara a nove anni di distanza assenza di dispnea da sforzo e di problemi di tipo respiratorio.

La tecnica chirurgica elettiva di riparazione del muscolo alterato è la plicatura del diaframma senza incisione o escisione della parte alterata del muscolo. La via di accesso oggi preferibile è la via laparotomica che è esente dai problemi della toracotomia e in genere consente abbastanza agevolmente la riparazione di tutti i difetti diaframmatici.

La plicatura del diaframma è un intervento semplice, efficace e duraturo senza peró poter determinare la completa ripresa funzionale normale del muscolo. La morbilitá e la mortalitá legata a questa tecnica è nulla o molto bassa, quest'ultima associata alle complicazioni dell'anestesia generale.

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