An Experimental Study of Plastic Synthetics in Thoracic Surgery

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Since Tuffier's original description of the extrapleural operation in 1891, the procedure has been subjected to various modifications, particularly the introduction of different plombe materials. Fat was probably the first solid plombe to be employed, but was discarded rather early because of its inherent deficiencies: lack of resistance to pressure and tendency to liquefy. Bear's introduction of the paraffin pack was a notable step forward, and indeed this method is still in use. Subsequently, in an attempt to find the ideal type of plombe, various investigators have used gauze, rubber dam, rubber balloons, muscle flaps, and oil. As in all therapeutics, the very multiplicity of the agents used attests to the universal lack of applicability of any one. However, some of the discredit which has accrued to the procedure stems not only from the individual substance themselves, but from the very nature of the operation. One of the most frequent and disastrous complications of the procedure is broncho-extrapleural fistula. This has been commonly attributed to perforation of large, peripherally placed cavities either by pressure of the plombe, or secondary to necrosis of the cavity wall following stripping of its parietal extrapleural blood supply. Although there is no universal agreement on the pathogenesis of broncho-extrapleural fistulae, there is some evidence that pressure of an extrapleural pack may play a part. Certainly, too, those series in which case selection has been carefully carried out with regard to size, type, and position of cavities have shown a notably low incidence of fistulae.1

The inadequacy of the plombe materials devised to date has led many phthisiologists to return to extrapleural pneumothorax as a definitive procedure or as a preliminary procedure to a permanent oleothorax. This approach has been particularly popular in Scandinavia and Mexico,2 and workers in those countries attribute its efficacy to meticulous attention to detail in its performance. In this country, extrapleural pneumothorax has not become widely popular, chiefly because of the technical factors in the operation, the difficulty encountered in maintaining the space, and the need

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for constant close supervision of the patient. The search for an ideal plombage material has for these reasons continued sporadically.

With the advent of plastic materials, attention was naturally directed to their possible uses in surgery. Methyl methacrylate, more commonly known as lucite, was first applied in surgery for the reconstruction of cranial defects by Kleinschmidt in 1941. Wilson and Baker investigated its properties as a plombage substance in 1944, and suggested in their report that it be used in the treatment of pulmonary tuberculosis. It is particularly worthy to note the several criteria they listed for an ideal material: 1) non-irritating, 2) non-carcinogenic and non-antigenic, 3) of light weight so as to obviate the danger of perforating pleura and lung, 4) insoluble and chemically non-reactive in body tissues, 5) radiolucent or almost so, and 6) capable of being molded to fit a body cavity through a relatively small incision.

Extrapleural pneumonolysis with lucite plombage was done at the National Jewish Hospital from 1947 to 1949 with a total of 89 operations in 73 patients. The overall results with regard to cavity closure and conversion of sputum have been good, but by no means perfect. The lucite spheres have not completely satisfied the criteria as set forth by Wilson and Baker, particularly in regard to their rigidity and tendency to produce pressure points on the extrapleural shelf. Their very shape militates against complete obliteration of the dead space, and although each sphere becomes surrounded by a hyalin capsule, the latter is an unstable avascular material, and a source of continued drainage if infection supervenes. Moreover, with a fibrotic contracted lung, or thick-walled cavity, there is tendency for displacement rather than collapse of the diseased area.

On the basis of these observations, it was felt worthwhile to investigate a series of plastic and other synthetic materials in an attempt to find a more suitable plombage substance.

**Experimental Studies**

Since the deficiencies of lucite had centered around its rigidity and shape, attention was directed toward plastic materials in sponge form. It was our opinion that a spongy material would compress evenly without the creation of pressure points, could be cut to fit an extrapleural space without residual dead space, and would not be subject to migration like lucite.

**Vinyl Copolymer**

The vinyl sponge initially used was manufactured in a small, local, plastics laboratory, and the physical characteristics varied.
with different lots. Eight dogs were used in this series, the sponge being placed extrapleurally. In all of the dogs surviving for two months or longer there was definitely a fibrous reaction of some degree encompassing the plastic. In one case the fibrous tissue appeared to be penetrating the sponge, which had become very rigid.

The chief shortcoming of this material was its lack of uniform physical properties and the ultimate variation in consistency achieved in vivo. Moreover, even with autoclaving supplemented by Zephiran washes there was some degree of fluid reaction evoked. This was apparently due to the difficulties in washing the chemical plasticizer out of the substance.

Polystyrene

Polystyrene was used in a group of four dogs. In the two animals surviving there was a definite fibrous response about the sponge, and in one case there was some gross invasion of the sponge with strands of fibrous tissue.

Polystyrene is a commercial plastic product, rather widely used for advertising displays. It has the disadvantages of rigidity, and flakes very easily when being cut. Moreover, sections of tissue surrounding the sponge revealed a rather intense inflammatory cellular reaction. Because of its rigidity and friability no further studies were done with this material.

Cellulose

Cellulose does not fall into the category of plastic, but its resiliency and physical characteristics suggested its inclusion in this study. The material used was a white fine-pore pure cellulose*, and contained no plasticizing agent of the type normally used in cellulose sponges for commercial purposes. A review of the literature failed to reveal any reference to its previous use in the body, other than for the purpose of a biopsy sponge.7

The use of this material was restricted to two dogs and rapidly abandoned, since it became evident quite early that an intense and necrotizing reaction was immediately produced.

Neoprene

Neoprene is a synthetic rubber, and was manufactured for our purpose in the form of a foam sponge by the DuPont Company. Moreover, in order to eliminate as far as possible any extrinsic material that might act as an irritant, the product was subjected to extensive treatment, including a total of 12 washes in various solvents, and was finally sterilized in open steam for 20 minutes,

*Supplied by the DuPont Co. of Wilmington, Delaware.
following which it was dried for 18 hours at 70 degrees C. In addition, it was autoclaved just before use to insure sterility.

The material was placed in four dogs as an extrapleural plombe. Two of the dogs expired in the early postoperative period from abscesses. The remaining two survived but later autopsy revealed chronic abscesses and inflammatory reaction. The neoprene remained soft and rubbery, and was moderately adherent to the wall of the space, but could be easily stripped with the finger. There were no underlying pleural adhesions.

The neoprene, while not as explosively reactive in vivo as the cellulose, was nevertheless quite toxic despite its subjection to an intensive series of soap, methanol, alcohol, and distilled water washes. Moreover, the dogs surviving over two months revealed a chronic inflammatory rather than a fibrogenic reaction.

Formalinized Polyvinyl Alcohol†

The use of this material in experimental animals was first reported by Grindlay and Clagett. It is a synthetic plastic in sponge form. In the dry state the material is hard and rigid, but becomes delicately soft and compressible when wet with water. Of all the materials employed in this study, it appeared to answer most closely the physical characteristics we desired in a plombage substance.

Eight dogs were used in this group. Three still survive and are being kept for long term follow-up. Of the five dogs reported here, [produced under the trade name “Ivalon” by Ivano, Inc.]

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FIGURE 1: Formalinized polyvinyl alcohol sponge (Ivalon).
three had pneumonectomies and two extrapleural procedures with sponge packs. Two of the pneumonectomized dogs died after short intervals, one in 16 days, and the other in 21 days. The autopsy findings in these two animals were practically identical. In spite of bronchopleural fistula with contralateral spread, the sponge had become firmly adherent to chest wall and pericardium and was stripped away with some difficulty.

The third pneumonectomized dog survived, and was sacrificed after an interval of five and one-half months. During this period the animal remained in excellent condition, ate well, and showed no signs of toxicity. At autopsy the right hemithorax was completely obliterated without mediastinal shift. This obliteration was particularly interesting in view of the fact that the sponge had originally filled only two-thirds of the pleural cavity. The plastic had become densely adherent to pericardium and venae cavae on the medial aspect, and to the chest wall laterally. The chest wall appeared to be drawn inward, and the intercostal spaces were contracted. The bronchial stump was firmly enclosed in fibrous tissue. The sponge had become firm and dry except in the costovertebral gutter where it retained some sponginess. Removal of

FIGURE 2: Low power microphotograph of formalinized polyvinyl alcohol sponge (Ivalon) removed from dog's chest after three months. (A) Sponge. (B) Heavy fibrous band running through body of sponge. (C) Looser fibrous tissue filling interstices of sponge.
the material had to be accomplished by sharp dissection, leaving a thin layer attached to contiguous structures.

Microscopic sections through the entire depth of the sponge revealed the pores and spaces completely infiltrated with loose and medium dense collagenous tissue, with few nuclei and some dilated capillaries. There was no pyogenic reaction. The bronchial stump also had a dense fibrous mucosa and outer coat without leucocytic response.

One of the animals with an extrapleural plombe developed a chronic infection in the space, but despite this survived in good condition until sacrificed at five and three-quarter months. Despite the infection, the sponge was firmly adherent to the walls of the space, and stripped with great difficulty. It remained soft and compressible.

The fifth animal, with an extrapleural plombe, was sacrificed at five and one-quarter months. The reaction in this dog was quite similar to the surviving pneumonectomized dog. The sponge was firmly enclosed in the extrapleural space, which was non-infected. The material was so densely incorporated that sharp dissection was required for its removal. The cortical portion of the pack had become dehydrated and firm, but the central portion remained soft and spongy.

The microscopic findings in this animal were likewise similar to those in the pneumonectomized dog. The outer thirds of the block revealed infiltration with relatively cellular fibrous tissue.

FIGURE 3: Microphotograph of formalinized polyvinyl alcohol sponge (Ivalon) inserted under scapula between stages of thoracoplasty. This was our first clinical trial of this material and when removed after three weeks was already markedly adherent. (A) Sponge. (B) Cellular reaction in sponge interstices. (C) Fibrous tissue already (3 weeks) lining the sponge interstices.
and some capillaries. The central third which grossly had appeared soft and spongy revealed a much looser fibrous invasion with residual open spaces and lacunae in the sponge which had not become infiltrated. There was no leucocytic response.

SUMMARY

A series of plastic and synthetic materials were subjected to in vivo study regarding their suitability as plombage substances. Of the five materials employed in this study, cellulose and neoprene appeared to evoke an early inflammatory and toxic reaction, and these were soon discarded. Vinyl sponge and polystyrene appeared to be relatively non-toxic, but did not compare favorably with the physical properties of formalinized polyvinyl alcohol. The latter material, in addition to its very desirable physical characteristics, appeared to have no toxic properties or undesirable chemical reactions in mammalian tissues. More important, it possesses the happy quality of producing a fibrogenic response to the extent that the plombe becomes completely infiltrated with fibrous and collagenous tissue. The findings in this study also suggest that the material may favor fortification of the bronchial stump with fibrous tissue. It would appear that clinical use of this material in selected cases is warranted.

RESUMEN

Se hicieron pruebas in vivo de una serie de materiales sintéticos para descubrir su adaptabilidad como substancias para el plombaje. de los cinco materiales que se emplearon en este estudio, la celulosa y el neoprene parecieron causar una temprana reacción inflamatoria y tóxica y pronto fueron abandonados. Esponjas de vinyl y el polistyrene parecieron ser relativamente no tóxicas, pero fueron inferiores en sus propiedades físicas al alcohol polyvinyl formalinizado. Este último material, además de sus muy deseadas características físicas, pareció no tener propiedades tóxicas o reacciones químicas nocivas sobre los tejidos de mamíferos. Y aún de mayor importancia es que posee la feliz cualidad de producir una respuesta fibrogénica hasta tal punto que el plombe llega a quedar completamente infiltrado con tejido fibroso y colagenoso. Los hallazgos en este estudio también sugieren que este material puede favorecer la fortificación del mufón bronquial con tejido fibroso. Parecería que está justificado el uso clínico de este material en casos seleccionados.

RESUME

Différentes substances plastiques et synthétiques ont été soumises à une étude in vivo au sujet de la possibilité de les utiliser comme
substances de plombage. Parmi les cinq substances employées, la cellulose te le "noéprène" semblaient causer une inflammation et des réactions toxiques, elles furent vite éliminées. Les éponges de "vinyl" et de "polystyrène" semblaient relativement non toxiques, mais elles ne purent soutenir une comparaison favorable avec les propriétés physiques de l'alcool polyvinique formalisé. Cette dernière substance, sans parler de ses caractéristiques physiques qui sont très favorables, a paru n'avoir aucune action toxique et n'a créé aucune réaction chimique fâcheuse sur les tissus des mammifères. Ce qui est particulièrement important, c'est qu'elle possède l'heureuse qualité de constituer une réaction fibrinogène dans la région environnante, si bien que le plombage se trouve entièrement infiltré de tissu fibreux et collagène. Les constatations faites dans cette étude font entrevoir également que cette substance peut favoriser la consolidation du moignon bronchique grâce à l'apport de tissus fibreux. Il semblerait que dans certains cas précis, l'utilisation clinique de cette substance soit autorisée.

REFERENCES