Progress in Thoracic Surgery and the Role of Reinforcement Materials
—Focusing on NEOVEIL-Tenting—

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Please tell us about recent progress in thoracic surgery.

Twenty years ago, a 30-cm-long skin incision was made and 2 ribs were cut through for lung cancer surgery. It was a huge burden on patients since it took 1-2 hours just to open and close the thorax. Since this method was used to open the thorax even when the detected lung cancer was small, it was not easy to offer this surgery to patients, and surgery was therefore sometimes delayed. When operating on a patient with pneumothorax, a 10- to 15-cm-long incision was made under the armpit. The armpit, only patients who developed pneumothorax repeatedly or who did not heal for a long time were subject to surgery.

The introduction of thoracoscopic surgery made it easier for patients to undergo surgery. The range of indications of thoracic surgery expanded, and the number of elderly patients or patients with small lung cancers increased dramatically. Patients with pneumothorax can now undergo surgery immediately after the onset, and the duration of hospitalization has been shortened. Thoracoscopic surgery does not only require a smaller skin incision, but also shortens the time needed to open and close the thorax, and even the duration of hospitalization. Thus, patients’ burden has been reduced dramatically.

What do you think about surgical strategy for lung cancer?

With the spread of high resolution CT and the introduction of PET, it has become possible to detect smaller lung cancers. Now that such lesions are resectable by thoracoscopic surgery, the number of surgical procedures in patients with early stage lung cancer situated in the periphery of the lung field, or in elderly patients with lung cancer who were previously not subject to surgery, have been increasing. Although it is standard procedure to perform a lobectomy even for small cancers, some institutions have recently started to perform reduction surgery in patients with early stage lung cancer with a favorable prognosis, based on the viewpoint of retaining pulmonary function. It has been reported that the treatment outcome of reduction surgery in selected patients is similar to that of lobectomy. The reason why this surgical method is drawing attention is that it is easy even to treat secondary cancer. The recurrence rate in patients who had developed lung cancer once is 16- to 32-fold that in patients who have never had lung cancer. Therefore, it seems more beneficial for patients with early stage lung cancer with a good prognosis to retain the pulmonary function as far as possible so that they will be able to prepare themselves for the possible onset of secondary or tertiary cancer. With reduction surgery, the ideal method may be segmentectomy, which allows anatomically correct resection. This method used to be performed reluctantly in patients with impaired pulmonary function. However, it may become the future standard surgery for patients with small lung cancer with a good prognosis.

Please tell us about the types and roles of reinforcement materials in thoracic surgery.

Ninety percent of the lung consists of air. Therefore, air leakage often occurs after lung resection. As mentioned before, ever since thoracoscopic surgery was introduced, the range of indications for surgery has expanded and there are more opportunities now to perform surgery in patients with impaired pulmonary function or elderly patients with lung cancer, whose lungs are vulnerable to develop air leakage easily. Air leakage greatly affects the operation time and the onset of post-operative complications. Therefore, the prevention of air leakage is a very important goal during thoracic surgery, alongside hemostatic procedures before the completion of the surgery. Procedures that stop air leakage sometimes used to take several hours. Reinforcement materials that can stop air leakage within a relatively short period of time, are indispensable to our surgery. It is extremely useful, especially when stopping air leakage from a stapled site or a resected surface of the lung without pleural membrane. It is considered important to control air leakage for the following reasons: the thoracic drain can be removed earlier, pain or restriction of activity associated with the drainage can be reduced, and moreover, the duration of hospitalization can also be shortened.

As for the materials, the pericardial membranes of cows, ePTFE, collagen sheets with fibrin glue, polyglycolic acid sheets (NEOVEIL), and fibrin glue are used. In our hospital, polyglycolic acid sheets (NEOVEIL) and fibrin glue are used concomitantly in thoracoscopic surgery since it is easy to use and can easily stop air leakage. NEOVEIL is used as the basic material and fibrin glue is sprayed around (Figure 1), especially for air leakage from lung parenchyma that is not covered by the pleural membrane on the organ side, such as the segmentectomy surface. With this method, it has become possible to remove the drain within 2 days after surgery in most patients.

Disadvantages of the reinforcement materials are rejection of the foreign substances because artificial substances or analogous tissues derived from animals are used, or due to contamination by plasma products such as fibrin glue. Therefore, such reinforcement materials are avoided as far as possible in patients with suspected thoracic infections or younger patients. On the other hand, I consider NEOVEIL as a useful material, because it is a synthetic substance that is absorbed by the body. However, NEOVEIL seems to induce pleural membrane adhesions at a later stage. These

Defect in the pleural membrane formed at the time of interlobar fissure formation

Coverage of the defective part with NEOVEIL

Figure 1
adhesions may be problematic in patients with lung cancer with a good prognosis who are expected to undergo surgery against secondary cancer on the same side. We will have an answer for this problem in 5 to 10 years from now.

—Please tell us about past and present techniques for pneumothorax surgery.

Twenty years ago, pneumothorax surgery consisted of auxiliary thoracotomy, the thorax was named opened at the upper intercostal site, and the scar was not conspicuous since it was under the armpit. Bullae from which air actually or possibly leaked were resected. To prevent recurrence of pneumothorax, the pleural membrane was abraded or chemical substances such as vibramycin were used to make it adhere at the completion of surgery. As a result, the post-operative recurrence rate was 3-5%.

Ever since thoracoscopic surgery was introduced, more patients were subjected to surgery, and surgery started to be performed at an earlier stage. Two or three ports are created, and bullae are resected using an automatic sealer. However, the post-operative recurrence rate of thoracoscopic surgery, which can reduce patients’ burden, has unfortunately increased to 10-15%, which is higher than with thoracotomy. The reasons for this high rate of recurrence are remaining bullae that failed to be removed during thoracoscopic surgery, and the fact that pleural membrane adhesion therapy is no longer used concomitantly. This is the result of using a non-invasive procedure, and should be resolved as soon as possible.

—Please tell us why reinforcement materials are used in young and elderly patients with pneumothorax.

The most typical kind of pneumothorax in elderly patients is emphysema. Air leaking bullae are multiple blisters, and air leakage commonly occurs from the stapled line after cutting with a stapler. In elderly patients with pneumothorax, it is important to stop air leakage during surgery. If the site that was cut with a stapler is reinforced with reinforcement materials and air leakage is controlled, the duration of hospitalization will be shortened and the patient will be discharged from the hospital sooner. Air leakage is controlled by stapling with a stapler, whereby reinforcement materials are attached or a NOOVEIL sheet is applied with fibrin glue on the resected margin. Once air leakage is controlled, recurrent onset at a later stage is not as problematic as in younger patients.

On the other hand, with pneumothorax in younger patients, air leakage is less frequent and surgery is easier even if bullae are resected with a stapler since most of the lung is normal, though a single or several bullae might be present. However, it is problematic that the post-operative recurrence rate is approximately 10%, which is extremely high. When such patients undergo surgery, new bullae are formed, not necessarily on the staple line, but near the stable line. When we treat younger patients at our hospital, we consider that, besides these bullae, small bullae are also present at the apex of the lung. Some may consider using the pleural membrane adhesion method concomitantly, but it is not strongly recommended in all patients, since it may impair respiratory function. Pneumothorax does not occur while children are growing. Most patients are of high school age or older, namely, they are no longer in the growth period, with a thin, flat chest. Some consider that bullae or blebs develop due to rapid growth of the thorax, which has prevented lung expansion, and pneumothorax occurs as a consequence. According to this hypothesis, even if bullae are resected, the remaining lung volume is reduced by the resected amount, and if the lung, which has been shrunk to a constant volume in the thoracic cavity, re-expands, the existing immature bullae will eventually appear as bullae. Therefore, it seems important not to over-expand the apex, which contains immature bullae, after resection of the lung apex. Considering these, in case pneumothorax in young adults developed due to bullae at the lung apex, we cover NOOVEIL the lung apex (NOOVEIL-Tenting) with NOOVEIL LL size (15cm x 15cm), which is larger than the usual size, after resecting the bullae. This size can adequately cover the resected margin of the bullae at the lung apex, and it can be securely applied without using any glue, including fibrin glue or the patient’s autodonated blood.

—Please tell us how to use NOOVEIL LL size and the treatment method.

Surgery is performed with 3 ports (1 video port and 2 operation ports) of 5mm diameter or larger. The treatment method is to resect some bullae at the lung apex and cover the apex with NOOVEIL LL size. NOOVEIL L size (10cm x 10cm) was used before, but it does not cover the entire area. Considering the size of the lung apex, a size of approximately 15cm x 15cm is appropriate. In 1 case of a 21-year-old male patient in whom NOOVEIL LL size was used after the resection of bullae at the apex of the left lung, a CT scan of the frontal section that was obtained 3 months after surgery, showed that the lung apex had clearly shrunk compared to the apex of the unoperated side, and no bullae were newly formed (Figure 2). This method seems effective to control...
overexpansion of the lung apex, compared to patients with recurrent pneumothorax who are not treated with NEOVEIL. This should be further investigated by accumulating more cases.

--- Do you have any tips for applying NEOVEIL LL size?
NEOVEIL-Tenting requires approximately 5-10 minutes on average to complete, whether performed by a surgery resident or a surgeon with 5-10 years experience. No special techniques are necessary, and it is not stressful. As mentioned before, it can be securely applied without using fibrin glue to fix the NEOVEIL. NEOVEIL LL size is inserted from a port, and after it is nicely spread across a wide area using forceps, it is moved to the apex of the lung. The apex of the lung should be covered entirely, including the mediastinal side, and reinforced so that excessive expansion of the lung apex is avoided (Figure 3).

--- Can you think of any other ways that the characteristics of NEOVEIL LL size could be advantageous?
NEOVEIL may be useful to reinforce defects in the diaphragm or the pericardial membrane. It should be used under slight tension-resistant conditions by using fibrin glue concomitantly. According to an experiment using both NEOVEIL and fibrin glue, the pressure-resistance seems to be extremely high. After repeating animal tests, we will consider if these can be applied clinically as reinforcement materials for the diaphragm or pericardial membrane. In addition, since the sealing effect on the lung parenchyma without pleural membrane seems high, it may be possible to cover the bottom of giant lung cyst bullae with a large sheet to stop air leaking.

--- Finally, how do you consider the future of reinforcement materials?
Measures against air leakage are an eternal theme for thoracic surgeons. Further improvement is necessary with these reinforcement materials to control air leakage. With regard to the effects of NEOVEIL, it is highly effective to seal air leakage by interaction with fibrin glue. However, late stage effects and risks are unknown. If adhesion to surrounding tissues is promoted, a double-surface sheet, with one side coated with an adhesion-resistant substance, may be needed.