論　文　内　容　要　旨

The differences in histological changes among pulmonary vessels divided with an energy device

(エネルギーデバイスを用いた肺血管の切離における組織学的変化の違い)

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Objectives: Open and endosurgical stapling devices have become the standard procedure for closing large pulmonary vasculatures, whereas small pulmonary vasculatures are manually ligated with a suture, or divided using a vessel sealing device (VSD). Advanced bipolar and ultrasound technologies are still being evaluated in some trials. Safe division of the pulmonary vasculature, especially the pulmonary artery (PA), during anatomical lung resection is critically important. Histological changes after division of the PA and pulmonary vein (PV) using the VSD are not fully understood. The present study aimed to histologically and immunohistochemically clarify how division with the device affects wall layers of the pulmonary vasculatures.

Methods: This prospective cohort study analyzed outcomes of 20 patients who underwent anatomical lung resection for the primary lung cancer or metastatic lung tumor at the Hiroshima University Hospital. After a single proximal ligation, PA and PV (diameter, 2 - 7 mm) were divided using a LigaSure Blunt Tip (LSB). Histological findings and thermal damage were evaluated in vascular specimens from resected lungs. Vessel diameters were measured immediately after retrieving lungs from the vessel adventitia to the adventitia ex-vivo using a caliper before formalin fixation in the operating room. Vessel stumps (22 PAs and 21 PVs) were fixed in 4% formalin, sectioned and stained with hematoxylin and eosin (H&E), Elastica van Gieson (EVG), Masson's trichrome (MT) and α-smooth muscle actin (α-SMA) antibody using standard procedures. The length of disruption was measured from the edge of the sealed zone to the farthest point of disrupted media of the PA. Thermal spread on the PA and PV was also measured from the edge of the sealed zone to the farthest area stained red with MT. The length of disruption and thermal spread were analyzed using the Wilcoxon rank sum test.

Results: All anatomical lung resections were straightforward with no intraoperative dehiscence or bleeding from the PA and PV. Repeated surgery for postoperative hemorrhage was not required and no other severe complications arose.

PA has a well-developed media with rich elastic fibers and thin adventitia, whereas PV comprises the thinner media and thicker adventitia with abundant collagen fibers. Vascular division of the PAs and PVs appeared complete to the naked eye. However, in all divided PAs, the intima and much of the disrupted media had invaginated into the lumen and the area adjacent to the sealed zone comprised only adventitia and thin disrupted media. Additionally, thermal energy generated by the LSB resulted in a wide range of thermal necrosis over the histologically fragile area in all cases. Conversely, the wall layers of all divided PVs were completely fused without disruption. Histological changes significantly differed between the pulmonary vasculatures after division using the LSB.

Thermal spread and disruption did not significantly differ between small (2 - 4 mm) and

large (5 - 7 mm) PA (187 [150 – 253] vs. 236 [190 – 275] μm, $P = 0.22$; 180 [138 – 200] vs. 210 [161 – 305] μm, $P = 0.22$). There was no difference in thermal spread between small (2 – 4 mm) and large (5 – 7 mm) PVs (208 [173 – 227] vs. 272 [190 – 347] μm, $P = 0.18$).

Discussions: Histological and immunohistochemical stains revealed histological fragility with thermal damage on wall layers of all PAs after division with the LSB. The intima and much of the disrupted media had invaginated into the lumen. Bipolar electrosurgical radiofrequency energy caused thermal damage on areas adjacent to sealed zones that comprised only adventitia and thin media. In contrast, the wall layers of all PVs were fused without disruption and invagination and areas adjacent to sealed zones seemed robust.

Our histological findings and quantitative assessments revealed that thermal damage and disruption could extend to the PA trunk if the proximal stump of a divided PA branch is contiguous to that. In order to avoid damage on the PA trunk, surgeons should apply VSD at a sufficient margin from the root of PA branch because intra- and postoperative bleeding caused by PA trunk injury can be catastrophic. In addition, adding a proximal ligation with absorbable suture materials that cause less inflammation and granuloma at arterial tissues around ligations might be acceptable, considering patient's age, complications, and administration such as steroid or anti-coagulant.

Conclusions: Histological changes significantly differed between the pulmonary vasculatures after division with the LSB. It remains unclear whether these findings could lead to a clinical risk. However, surgeons should consider that dividing with vessel sealing devices might have more histological impact on the wall layers of the PA compared with the PV.