Lessons learned on a new procedure: Non-Sternotomy Minimally Invasive Pulmonary Embolectomy

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Abstract

Since publication of our initial experience with non-sternotomy minimally invasive pulmonary embolectomy (MIPE) via a left mini thoracotomy, we have expanded our experience, refined the operation and streamlined the post-operative management of patients. Our initial publication described three patients who underwent MIPE.1 We described our technique which included peripheral cardiopulmonary bypass (CPB) via femoral arterial and venous cannulation, left sided 5cm anterior thoracotomy in the 3rd intercostal space, identification and incision of the main pulmonary artery distal to the pulmonic valve, extraction of clot with subsequent primary closure of the pulmonary artery, and use of a 5mm, 30 degree laparoscope as an adjunct to assess clearance of the pulmonary artery.2 The patients included in this series had no post-operative complications, had a mean hospital length of stay of three days with mid-term follow-up up to 8-months revealing no untoward complications of the procedure. With early success of the MIPE at our institution, we began employing it preferentially over sternotomy with central CPB and pulmonary embolectomy. Since initial publication of our results, we have performed the MIPE in two additional patients with excellent outcomes. We herein present augmentations we've made to the procedure with a case-presentation which highlights these adaptations.

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Dear Editor(s) and Reviewers,

Journal of Cardiac Surgery

Please find within our manuscript entitled '**Lessons Learned on a New Procedure: Non-Sternotomy Minimally Invasive Pulmonary Embolectomy** .'

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Thank you for your time and consideration.

Sincerely,

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Introduction:

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With early success of the MIPE at our institution, we began employing it preferentially over sternotomy with central CPB and pulmonary embolectomy. Since initial publication of our results, we have performed the MIPE in two additional patients with excellent outcomes. We herein present augmentations we've made to the procedure with a case-presentation which highlights these adaptations.

Case presentation:

Pre-operative Course:

A 48 year old male with history of morbid obesity (BMI: 44 kg/m2), C4-C5 laminectomy and partial thyroidectomy one month prior presented to his local emergency room with new dyspnea on exertion ongoing for two days followed by a syncopal episode. He had no family history of clotting disorders and denied alcohol or tobacco use. On presentation he was normotensive, tachycardic and hypoxic requiring supplemental oxygen. Pulmonary Embolism (PE) protocol- Computed Tomography (CT) demonstrated a saddle pulmonary embolus extending into bilateral main pulmonary arteries and into segmental and subsegmental pulmonary artery branches bilaterally. Additionally, evidence of right ventricle strain was noted with right ventricular size larger than left ventricle in diastolic phase (Image 1). The patient was heparinized and transferred to our institution. Upon arrival, he was persistently tachycardic and hypoxic. Laboratory evaluation was notable for an elevated B-type natriuretic peptide (BNP) of 620 ng/L. Transthoracic echocardiogram revealed severely enlarged and poorly contractile right ventricle. Left ventricular contractility and valvular assessment was grossly normal. Bilateral lower extremities venous duplex ultrasound revealed a left common femoral deep venous thrombosis. Based on his extensive clot burden, evidence of acute right heart failure, pulmonary embolectomy was advised, and the patient proceeded to the operating room urgently for MIPE.

Operation:

Our surgical approach was as previously described.[1] We positioned the patient supine with a bump underneath the left shoulder blade to elevate the left hemithorax and extend the neck. Double lumen endotracheal intubation was used to achieve left lung isolation and a transesophageal echocardiography (TEE) probe was placed. A 5cm parasternal anterior thoracotomy was made in the third intercostal space (Image 2). Two inches of subcutaneous fat made visualization difficult. A mini-mitral retractor (Estech, AtriCure Corporate Headquarters 7555 Innovation Way Mason, OH 45040 USA) was used to facilitate exposure. The pericardium overlying the right ventricular outflow tract was identified and opened in parallel direction to the Right Ventricular Outflow Tract–Pulmonary Artery. Traction sutures were applied to the edges of the incised pericardium.

With this exposure, we realized that our incision was too inferior, in that the right ventricle was preferentially exposed rather than the body of PA (Image 3). In hindsight a second intercostal space incision would have been better for isolation of the main PA. In order to better facilitate exposure, we placed a simple retraction suture in the main PA to pull it inferior. We were also prepared to resect a portion of the second rib, but such was not required.

The right common femoral vein and artery were exposed in a standard fashion. The patient was fully heparinized and cannulation of the common femoral vein (wire-guided 25-French Medtronic venous cannula extending into the right atrium verified by transesophageal echocardiography) and artery (wire-guided 18-French Femoral-Flex cannula) was accomplished. Due to the deep layer of subcutaneous fat encountered, we decided to tunnel the cannuli through separate stab incisions. This facilitated the insertion of needle and guide wire into target vessels followed by dilation of each vessel and proper TEE guided placement of wires and cannuli with minimal line kinking and enhanced ergonomics (Image 4).

Once the ACT (Activated Clotting Time) was confirmed to have reached above 400 seconds, cardiopulmonary bypass (CPB) was initiated. At that point, a one-inch incision was made in the main pulmonary artery in order to insert ring forceps and extract the clots. Although full cardiopulmonary bypass with approximately 5 L/min was ongoing, bleeding from the PA incision was significant making visualization difficult thus requiring simultaneous suctioning through the limited surgical incision in order to identify the clots. Nevertheless, with vigorous suctioning employed to clear the main PA, we were able to identify two large clots, grasp each with endoscopic-type ring forceps and extract the target clots each measuring about 8 inches (Image 5), from the right and left pulmonary trunks.

Further investigation and review of the intraoperative TEE images revealed that the venous cannula had slipped back toward the right atrial (RA)-IVC junction rather than being high up in the mid RA, thus leaving volume undrained and the right ventricle relatively full. Furthermore, we suspected that the flow of 5 L/min was not adequate to empty the heart in this large patient with BMI of 44 who had evidence of fluid overload based on preoperative echocardiography and CT scan. With this in mind, we should have deployed dual venous cannulas (placed via the common femoral vein into the RA and a second percutaneously placed superior vena cave (SVC) cannula inserted under TEE guidance via the right internal jugular vein). We believe dual percutaneous cannulation and confirmation of accurate position by TEE is advisable in large patients and would prevent this undue hardship of exposure and clot retrieval.

Once the two large clots were extracted, the pulmonary arteriotomy was closed with multiple pledgetted 3-0 prolene stitches, instead of the usual running two-layer closure. This technique facilitated repair of the pulmonary artery while applying suction to clear the bleeding from the surgical site, given inadequate venous drainage.

The patient was then weaned off cardiopulmonary bypass without difficulty. Cardiac function was assessed via TEE and the right ventricle remained dilated however function had improved to only mildly depressed systolic function (compared with severely depressed systolic function pre-operatively). Hemostasis was ensured and two chest tubes were placed through separate entry points into the fourth intercostal space. The anterior thoracotomy was closed in standard fashion and decannulation followed by repair of femoral vessels with resultant excellent distal pulses in the femoral artery.

In a follow-up case, and after learning from the aforementioned experience, we modified our technical approach by making the anterior thoracotomy incision in the second intercostal space, inserting a second percutaneous cannula in the SVC, and placing a 2 cm purse-string suture about the pulmonary arteriotomy prior to incision which was sufficient to seal the pulmonary artery entry point at the end of the procedure.

Post-operative course **:**

Aerosolized Epoprostenol Sodium (Flolan) was initiated in the operating room prior to transport to the ICU to support right ventricular function. The patient required inotropic and ventilatory support until post-operative day (POD) 3 at which point he was extubated. Flolan was weaned based on a combination of central venous gas oxygen saturation, central venous pressure and echocardiographic assessment of RV function given absence of a PA catheter to assess right heart function. Notably, the patient had a known left femoral DVT pre-operatively, and an IVC filter was placed on POD 3 as a safeguard for further pulmonary embolism. His hospital course was further complicated by thrombocytopenia and non-oliguric acute kidney injury with coinciding hyperkalemia, requiring one session of hemodialysis. Given exposure to heparin, a heparin-induced thrombocytopenia (HIT) immunoglobulin and serotonin release assay were sent and both were positive. Heparin was discontinued, Argatroban was initiated and ultimately transitioned to coumadin. Extensive post-operative mobilization and physical therapy were required for convalescence due to extended ICU stay, patient size, and a recurrence of severe gout that immobilized him for several days. Ultimately, the patient discharged on POD 19 not requiring dialysis or supplemental oxygen, ambulating and tolerating a diet.

Our most recent patient who underwent MIPE for massive saddle PE, and the fifth patient in our series total, underwent the procedure, was extubated on POD 0, transferred to the general care floor on POD 1 and discharged home on POD 3.

Discussion:

Pulmonary embolism is a major cause of cardiovascular mortality.[3] Most clinical guidelines only recommend surgical embolectomy for massive PE and only when thrombolysis has failed, is contraindicated, or for patients presenting in extremis with cardiopulmonary collapse.[1,4] Emerging data from our institution and others support the extended utility of surgical embolectomy for treatment of massive PE. As we previously wrote, recent reports highlighting improved surgical techniques have shown that surgical pulmonary embolectomy yields similar 30-day and 5-year mortality rates compared to thrombolytic therapy. [5,6]However, compared to thrombolysis, surgical pulmonary embolectomy was associated with lower rates of bleeding complications, stroke, and requirement for re-intervention within 30 days.[6]

Our introduction of the MIPE via a left mini thoracotomy highlights an advancement in surgical embolectomy in that it avoids sternotomy and related complications allowing for enhanced recovery. With continued experience with the MIPE we offer the following as important lessons learned after our initial description[1].

1. Location of the anterior thoracotomy should be based on pre-operative axial and sagittal imaging rather than adhering to a standardized third interspace. In the case presented the 3^{rd}intercostal space was too inferior and created difficulty with exposure and visualization of the PA. The subsequent MIPE procedures done at our institution have been performed via the 2^{nd} intercostal space with improved exposure and ease of surgery.
2. Appropriate venous drainage of the heart is important to successfully complete the operation. In the case presented, the single venous drainage catheter placed from the femoral vein going up into the right atrium may have slipped back into the IVC during surgery, or was not capable of sufficient drainage in the large patient, or combination of both factors, thus causing the right ventricle to not adequately decompress and forced us to rely on robust suctioning within the pulmonary arteriotomy to successfully complete the case. We now employ dual venous drainage (placed via the common femoral vein into the RA and the internal jugular vein into the SVC-RA junction) to ensure proper venous drainage which

allowed for improved visualization and clot extraction.

3. Closure of the pulmonary arteriotomy can be much more easily facilitated by placement of a purse-string suture about the planned arteriotomy prior to incision. We intend to employ this technique, here forward, for PA closure.
4. Early utilization of Aerosolized Epoprostenol is an important adjunct to aid the recovering right ventricle.
5. Care of patients with massive pulmonary embolism requires a team based, multi-disciplinary approach. The care of this patient involved consulting services including vascular surgery, hematology, nephrology, physical therapy and social work services.
6. While we have demonstrated a low rate of complications, and zero mortality from this procedure in our previous report[1], the case presented highlights that while we were able to perform the MIPE, complications did still occur (prolonged ventilatory and inotropic support to aid the recovering right heart, AKI, HIT) and are to be expected with any patient who requires surgery for pulmonary embolus due to the inherent risk of cardiopulmonary bypass. Even so, we believe that recovery from the small mini anterior thoracotomy as described compared to a standard sternotomy may be easier and simpler for patients.

In summary, we have detailed several augmentations to our original description of the MIPE.[1] We believe the operation and results are reproducible and can be a valuable tool in the armamentarium of the cardiothoracic surgeon.

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Image 1: Computed tomography showing: (A) saddle pulmonary embolus (B) right ventricle strain with right ventricular size larger than left ventricle in diastolic phase.

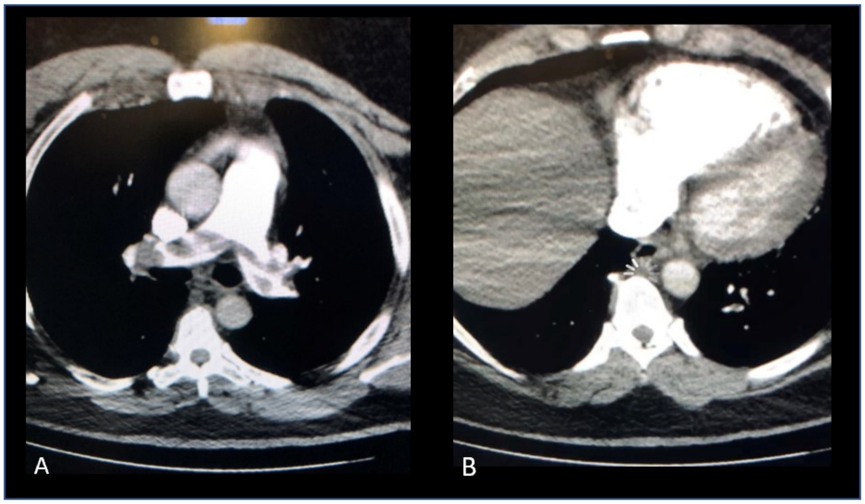


Image 2: Pre-operative marking of incision at 3rdintercostal space.

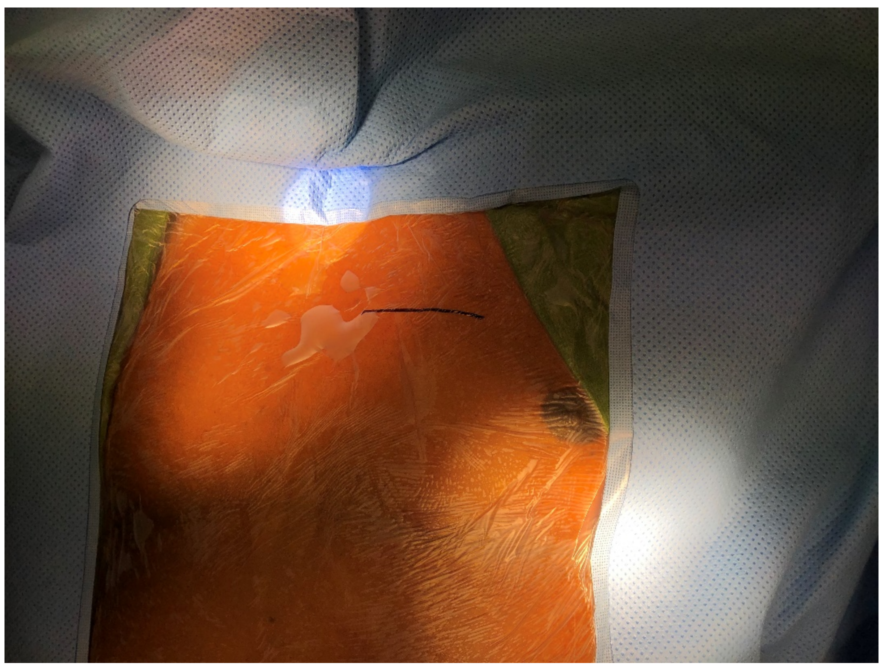


Image 3: Anterior left thoracotomy with mini-mitral retractor in place at 3rd intercostal space. Right ventricle, not PA, is immediately beneath and visualized, highlighting need for higher incision at 2nd intercostal space.

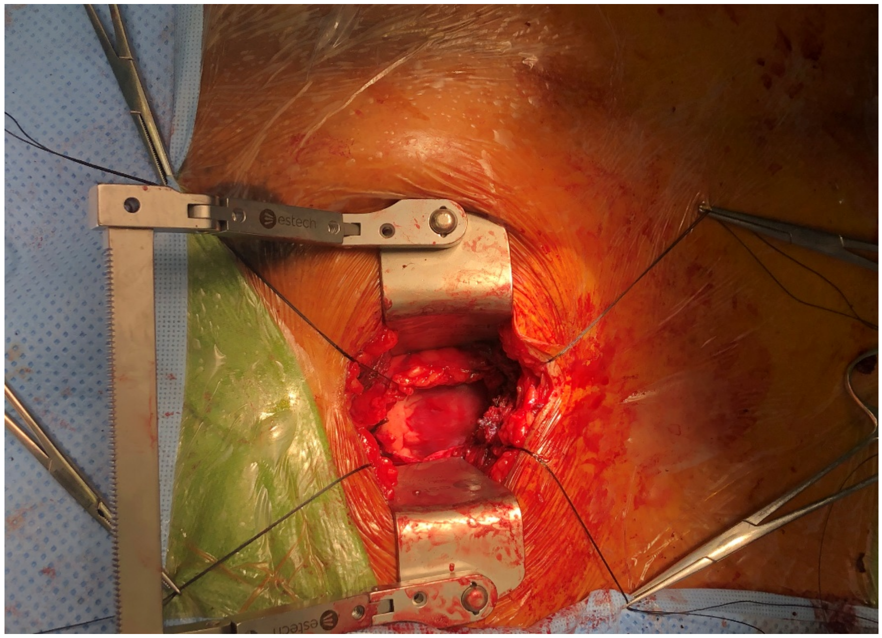


Image 4. Femoral arterial and venous cannulation for peripheral cardiopulmonary bypass.

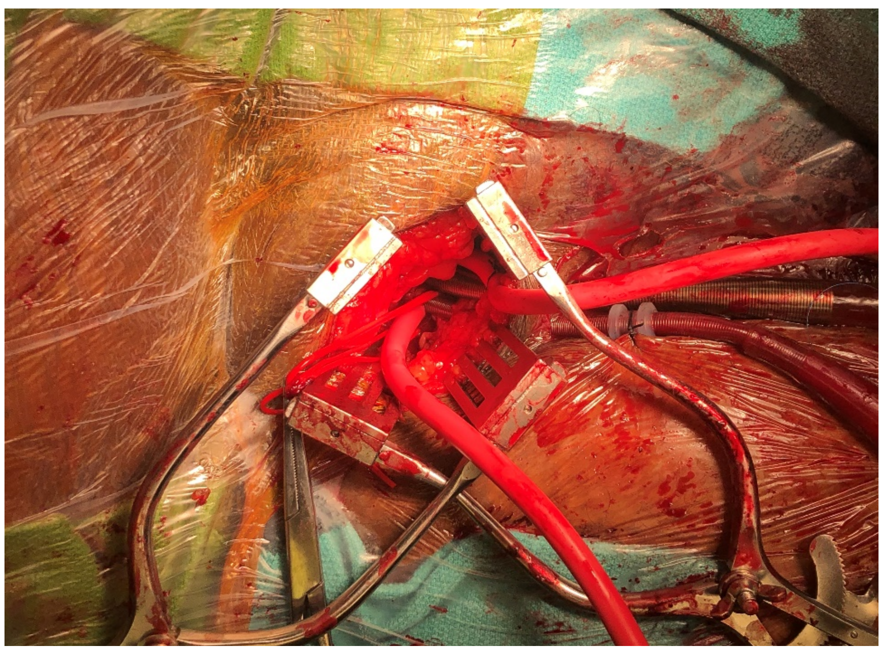
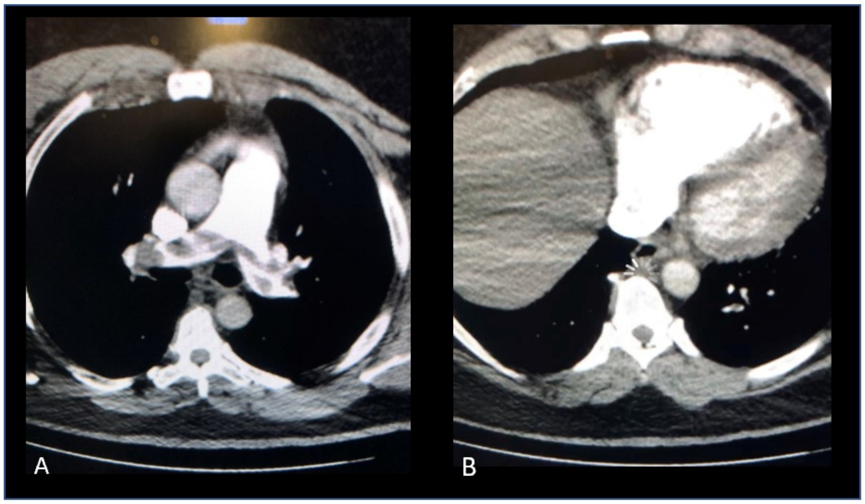


Image 5: Pulmonary embolectomy specimen.

Image 6: Closed incision with two drainage chest tubes in place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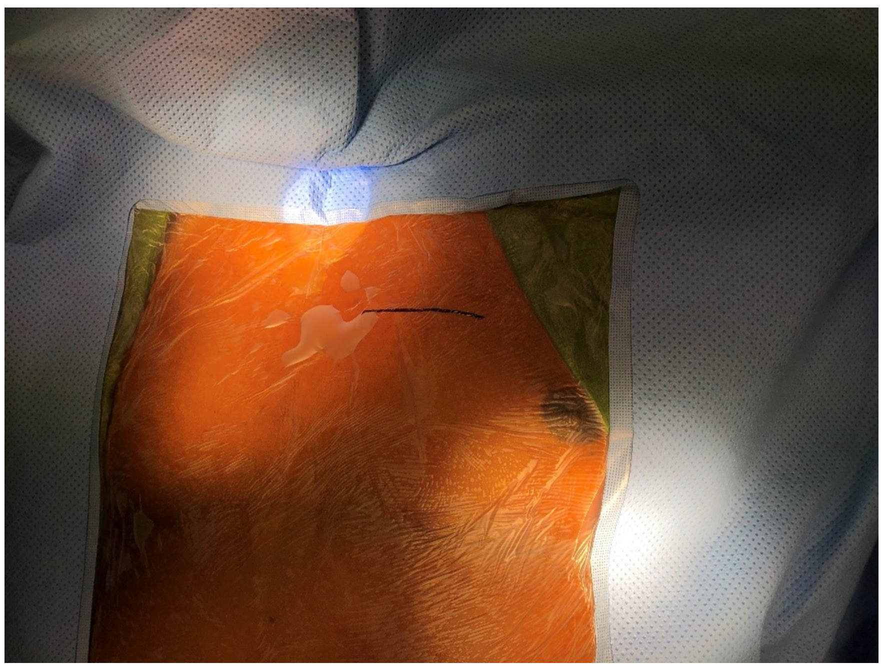

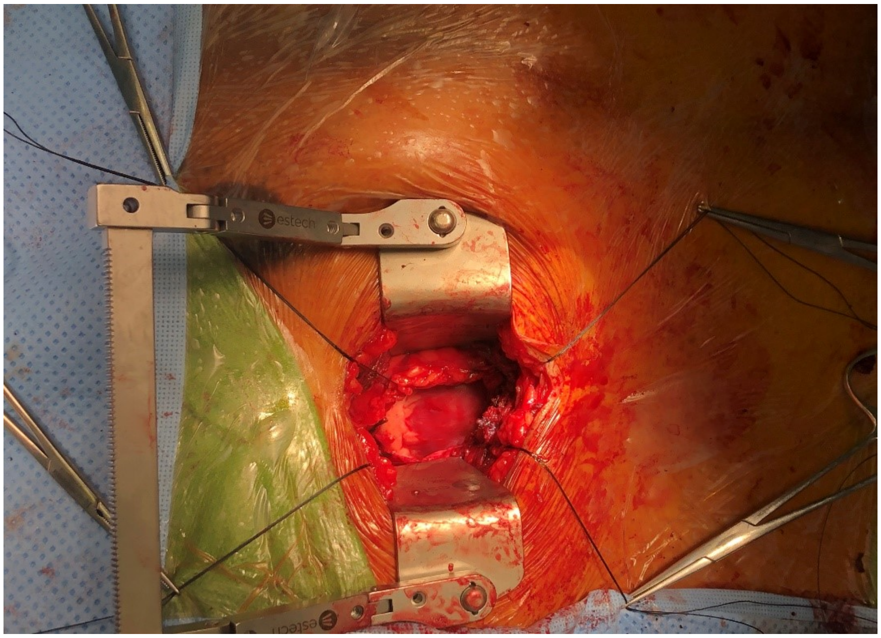
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