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Review

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Traumatic pulmonary artery injury: a review of the recent literature

Youichi Yanagawa, Kouhei Ishikawa, Hiroki Nagasawa, Ikuto Takeuchi, Kei Jitsuiki, Hiromichi Ohsaka, Kazuhiko Omori

Department of Acute Critical Care Medicine, Shizuoka Hospital, Juntendo University, Izunokuni 410-2295, Shizuoka, Japan.

Correspondence to: Dr. Youichi Yanagawa, Department of Acute Critical Care Medicine, Shizuoka Hospital, Juntendo University, 1129 Nagaoka, Izunokuni 410-2295, Shizuoka, Japan. E-mail: yyanaga@juntendo.ac.jp

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Abstract

Pulmonary artery injury (PAI) is rare, lethal clinical entity. Traumatic PAI is anatomically classified into transection/rupture/laceration, pseudoaneurysm, dissection and fistula. In addition, traumatic PAI is clinically classified into two major categories: iatrogenic and non-iatrogenic, depending on the mechanism of the trauma. The frequency, clinical symptoms and treatment differ between the two clinical categories. If PAI can be managed appropriately and promptly in patients without cardiac arrest, the patient may be saved, as PAI can be easily controlled with appropriate procedures due to the low pressure in the PA circulation.

Keywords: Pulmonary artery, trauma, iatrogenic

INTRODUCTION

Pulmonary artery injury (PAI) is a rare, lethal clinical entity. Most vital emergencies involve proximal PAI. However, if PAI can be managed appropriately and promptly in patients without cardiac arrest, the patient may be saved, as PAI can be easily controlled with appropriate procedures due to the low pressure in the PA circulation, provided the injury site is small[1]. In this review article, traumatic PA is anatomically classified into four categories and clinically classified into two major categories: iatrogenic and non-iatrogenic, depending on the mechanism of the trauma. The frequency, clinical symptoms and treatment differ between the two clinical categories. The references are limited to reports in the English literature published since 1990.

ANATOMICAL CLASSIFICATION

Anatomically, traumatic PAI is classified into transection/rupture/laceration, pseudoaneurysm, dissection and fistula.

A transection, rupture, disruption, perforation, tear or laceration of the PA is thought to be a near-complete tear through all layers of the PA due to trauma; however, there is no consistent definitive terminology[1]. Clinical symptoms due to such trauma include cardiac arrest or hemodynamic insufficiency due to massive hemorrhaging or cardiac tamponade, and dyspnea due to hemothorax or hemoptysis[1,2]. Chest pain due to concomitant thoracic cage injury has also been reported. Rarely, this PAI, which involves hemostasis by clotting, is incidentally found on enhanced computed tomography (CT) without specific symptoms, as whole-body enhanced CT is routinely performed in patients following a high-energy accident[3,4].

A pseudoaneurysm is an encapsulated hematoma in communication with the lumen of a ruptured vessel. This may form when re-epithelialization of the perforation does not occur, and a delayed diagnosis can occur even 60 years later[5]. The pseudoaneurysm may stabilize and spontaneously resolve or expand and rupture, depending on the etiology, size and intravascular pressure[1]. A pseudoaneurysm can be asymptomatic or characterized by symptoms of hemoptysis, shortness of breath and chest pain[6,7]. An iatrogenic pseudoaneurysm of the PA is most common, followed by trauma-induced events. A pseudoaneurysm of the PA can also be congenital or have a non-traumatic cause, which includes infections and neoplasms[6,7].

An arterial fistula is an abnormal connection between the artery and other lumen organs. If an abnormal connection between an artery and a vein occur, this is called as an arteriovenous (AV) fistula. In a trauma setting, arterial fistulas can be asymptomatic or characterized by right ventricular dysfunction, acute respiratory failure or transient ischemic attack (TIA)[8-12]. Traumatically, fistulas occur between the PA and left atrium, internal mammary artery, aorta or pulmonary vein. Non-traumatic pulmonary AV fistulas can also be associated with hereditary hemorrhagic telangiectasia[13]. The initial clinical manifestations include thrombotic or embolic stroke, brain abscess and TIA but can also be asymptomatic in non-traumatic cases[13]. The clinical trial of cyanosis, exertional dyspnea and digital clubbing is common, but there have been no reports describing triads due to trauma[13].

PA dissections (PADs) are created by the occurrence of a small tear in the tunica intima, which allows blood to enter and cause the intima layer to strip away from the media layer, in effect dividing the muscle layers of the vascular wall. The mechanism of blunt traumatic PAD is likely similar to that seen in the aorta as a result of shearing forces and differential deceleration of the mediastinum and the spine. However, unlike aortic dissection, PAD progresses rapidly and typically ruptures rather than developing a reentry site, which causes cardiogenic shock or sudden death, especially in non-traumatic cases with pulmonary hypertension[14]. Five major etiological groups can be identified: congenital malformation, infection or inflammation, acquired cardiac diseases, iatrogenic causes and trauma[15-17]. Traumatic PADs usually resolve or remain stable unless associated with pulmonary hypertension, in which case the risk of bleeding can be quite high[1,16].

IATROGENIC PAI

The most common cause of PA ruptures and pseudoaneurysms is iatrogenic, with PA catheters being a particularly common culprit[2,18-20]. Other iatrogenic causes include intraoperative surgical procedures[21-24], indwelling chest tubes[25,26], pacemaker implantation[27], central venous catheterization[28] and Kirschner wire migration[29].

The incidence of PAI induced by catheters is not very high, averaging 0.01%-0.47%[2]. The mortality rate of PAI induced by catheter averages 50% but can be as high as 75% in anticoagulated patients. If death

occurs, it is usually secondary to asphyxia rather than hypovolemia[2]. The initial presentation may be as obvious as massive pulmonary hemorrhaging or as subtle as a cough associated with minimal hemoptysis, or it may even be totally asymptomatic[30].

When catheter-induced PAI happens during insertion of a fluoroscope, it is relatively easy to retract the PA catheter a few centimeters and re-inflate the balloon under direct vision. It may therefore be possible to stop the bleeding[2]. Additional diagnostic angiography and embolization also can be easily performed at that point.

In addition to treatments for PAI, the patient may need selective intubation to obtain lung isolation in accordance with clinical symptoms. Lung isolation can be performed with different techniques, including selective intubation with a standard endotracheal tube, bronchial blocker or double-lumen tube (DLT)[2]. A bronchial blocker can be used for lung separation when a DLT is not immediately available or when it is difficult to insert the DLT. Bronchial blockers can be used to tamponade the bleeding side while waiting for diagnostic and therapeutic interventions. The most important aspects of treatment are lung isolation using selective intubation, bronchial blockers, or DLT as a temporary measure; rapid movement is important for more definitive therapy as it can avoid clotting of the entire lung on one side, which effectively causes pneumonectomy. Surgery, including pulmonary artery ligature, segmentectomy, lobectomy or pneumonectomy, is reserved for extreme cases, since these procedures are technically challenging and entail high morbidity[2].

NON-IATROGENIC PAI

A majority of non-iatrogenic PAI cases occur due to chest trauma; however, most chest trauma cases do not involve PAI. PAI accounts for a small percentage of thoracic trauma cases. Epidemiologically, Kulshrestha *et al.*[31] reported 102 patients sustaining cardiac injuries over a 4-year period. There were 45 blunt trauma, 36 stab injuries, and 21 gunshot injuries[31]. The injury involved the ventricle in 85 patients, atrium in 7 and the PA in 5 (5%) and resulted in crush injury to the heart in the remaining 5 cases. Thirty-three patients (32.3%) died at the scene, and 58 (56.9%) died during transportation. Only 11 patients (10.8%) reached the hospital alive, and 10 of these survived following thoracotomy and repair of the cardiac injury. The patients with ventricular injuries had a greater prehospital mortality than those with atrial or PA injuries.

Deneuville[32] reported 88 cases of penetrating chest trauma, focusing on non-iatrogenic PAIs. Of these 88 cases, 6 with PAI reached the hospital alive[32]. All cases underwent urgent operation, and 4 survived. The mortality appears to be high in patients presenting with complex lesions involving vascular and pulmonary structures. As a result, they concluded that isolated injuries of the PA were amenable to surgical repair and had a good prognosis if the patients arrived at the hospital alive.

We summarized the cases of non-iatrogenic PAI in Tables 1 and 2. Most cases were reported as case reports, except for the findings of Deneuville[32]. Penetrating injuries were more frequent than blunt ones. Similar to Deneuville[32], 46/50 (92%) cases survived. The diagnosis was made based on intraoperative findings, enhanced CT or pulmonary arteriography. The main treatment method was surgery or an interventional approach. These findings suggest that if hemorrhaging is not noted and the vital signs are stable, conservative treatment can be selected. There are no strict guidelines concerning the management of PAI, and the preferred approach depends on the lesion, patient and institution[1].

CONCLUSION

PAI is a rare, lethal clinical entity; most vital emergencies involve proximal PAI. Anatomically, traumatic PAI is classified into transection/rupture/laceration, pseudoaneurysm, dissection and fistula. Iatrogenic

Table 1: Cases of non-iatrogenic injury of the pulmonary artery since 1990

No.	Reporter	Year	Age (year)	Gender	Type of injury	Cause of injury	Type of injury	Symptom	Treatment	Outcome	Arrest	Other
1	Demondion *et al.*[33]	2016	27	Male	Blunt	Snowmobile accident	Rupture	Mediastinal hematoma	Conservative	Survive	None	
2	Maury *et al.*[34]	2015	51	Male	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
3	Lin *et al.*[35]	2014	23	Male	Blunt	Traffic accident	Rupture	Hemothorax	Ligation	Dead	None	MOF
4	Muthialu *et al.*[36]	2013	5	Female	Blunt	Traffic accident	Rupture	Hemothorax	Suture & lobectomy	Survive	None	
5	Vendrell and Gahide[3]	2010	42	Female	Blunt	?	Rupture	Hemothorax	Conservative	Survive	None	
6	Pereira and Narrod[37]	2009	55	Female	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
7	Kanani *et al.*[38]	2002	31	Male	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
8	Ambrose *et al.*[39]	2000	69	Male	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
9	Weltman *et al.*[40]	1999	69	Male	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
10	Clements *et al.*[41]	1997	42	Female	Blunt	Traffic accident	Rupture	Tamponade	Suture	Survive	None	
11	Daon and Gorton[42]	1997	44	Female	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
12	Katz and Groskin[43]	1993	27	Female	Blunt	Traffic accident	Rupture	Hemothorax	Suture	Survive	None	
13	Ohsaka *et al.*[44]	2015	91	Male	Penetrating	Sord	Rupture	Hemothorax	Suture	Survive	PEA	
14	Greberski *et al.*[45]	2015	36	Male	Penetrating	Knife	Rupture	Hemothorax	Suture	Survive	None	
15	Senanayake *et al.*[46]	2012	54	Male	Penetrating	Stab	Rupture	Hemothorax	Suture	Survive	PEA	
16	Sanchez *et al.*[47]	2010	31	Male	Penetrating	Stab	Rupture	Hemothorax	Suture	Survive	None	
17	Atalay *et al.*[48]	2010	18	Male	Penetrating	Gun	Rupture	Hemothorax	Suture	Survive	None	
18	Deneuville[32]	2000	32	Male	Penetrating	Knife	Rupture	Hemothorax	Suture	Survive	None	
19	Deneuville[32]	2000	37	Male	Penetrating	Shotgun	Rupture	Hemothorax	Suture	Survive	None	
20	Deneuville[32]	2000	24	Male	Penetrating	Knife	Rupture	Hemothorax	Suture	Survive	None	
21	Deneuville[32]	2000	22	Male	Penetrating	Shotgun	Rupture	Hemothorax	Pneumonectomy	Dead	Yes	
22	Deneuville[32]	2000	55	Male	Penetrating	Bull horn	Rupture	Hemothorax	Pneumonectomy	Dead	Yes	
23	Deneuville[32]	2000	44	Male	Penetrating	Knife	Rupture	Hemothorax	Suture	Survive	None	
24	Babatasi *et al.*[49]	1999	69	Male	Penetrating	Gun	Rupture	Mediastinal hematoma	Suture	Survive	None	
25	Kiss *et al.*[50]	1999	34	Woman	Penetrating	Gun	Rupture	Tamponade	Suture	Survive	None	
26	Jain[51]	1998	7	Male	Penetrating	Air gun	Rupture	Tamponade	Suture	Survive	PEA	
27	Goel *et al.*[52]	2013	58	Female	Blunt	Traffic accident	Pseudoaneurysm	No specific	Conservative	Survive	None	
28	Sridhar *et al.*[53]	2010	32	Male	Blunt	?	Pseudoaneurysm	No specific	Embolization	Survive	None	
29	Reade *et al.*[54]	2006	57	Male	Blunt	Traffic accident	Pseudoaneurysm	No specific	Conservative	Survive	None	
30	Kasai and Kobayashi[55]	1992	17	Male	Blunt	Traffic accident	Pseudoaneurysm	No specific	Lobectomy	Survive	None	
31	Goel *et al.*[52]	2013	32	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Conservative	Survive	None	
32	Quartey and Jessie[56]	2011	21	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Coil embolization	Survive	None	
33	Blanié *et al.*[57]	2011	39	Male	Penetrating	Circular saw	Pseudoaneurysm	No specific	Pericardial patch	Survive	None	
34	Rai *et al.*[58]	2010	28	Woman	Penetrating	Gun	Pseudoaneurysm	No specific	Coil embolization	Survive	Yes	
35	Maddali *et al.*[59]	2007	35	Male	Penetrating	Knife	Pseudoaneurysm	No specific	Suture	Survive	None	
36	Khan *et al.*[60]	2005	50	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Coil embolization	Survive	None	
37	Dimarakis *et al.*[61]	2005	29	Male	Penetrating	Knife	Pseudoaneurysm	No specific	Coil embolization	Survive	None	
38	Block *et al.*[7]	2004	40	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Coil embolization	Survive	None	

39	de Jonge *et al.*[62]	2003	57	Male	Penetrating	Knife	Pseudoaneurysm	No specific	Coil embolization	Survive	None	
40	Donaldson and Ngo-Nonga[63]	2002	17	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Lobectomy	Survive	Yes	CPC4
41	Savage *et al.*[64]	1999	49	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Coil embolization	Survive	None	
42	Hubler *et al.*[65]	1997	20	Male	Penetrating	Knife	Pseudoaneurysm	No specific	Lobectomy	Survive	None	
43	Huet *et al.*[66]	1996	29	Male	Penetrating	Gun	Pseudoaneurysm	No specific	Stent	Survive	None	
44	Giglioli *et al.*[10]	2013	46	Female	Blunt	?	Fistula (aortopulmonary)	Right cardiac failure	Pericardial patch	Survive	None	
45	Rrapo *et al.*[11]	2013	20	Male	Penetrating	Gun	Fistula (pulmonary)	ARDS	Pericardial patch	Survive	None	
46	Roshanali *et al.*[12]	2012	48	Female	Penetrating	Missile debris	Fistula (pulmonary)	TIA	Plug occlusion	Survive	None	
47	Howell *et al.*[67]	2004	24	Male	Penetrating	Knife	Fistula (aortopulmonary)	No specific	Operation	Survive	None	
48	Kerr and Sauter[68]	1993	35	Male	Penetrating	Knife	Fistula (pulmonary)	Short of breath	Embolization	Survive	None	
49	Almdahl *et al.*[16]	2014	46	Female	Blunt	?	Dissection	No specific	Conservative	Survive	None	
50	Chung *et al.*[17]	2009	53	Male	Blunt	Boat accident	Dissection	No specific	Nitric oxide	Dead	None	

?: not described; ARDS: acute respiratory distress syndrome; TIA: transient ischemic attack; MOF: multiple organ failure; PEA: pulseless electrical activity; CPC: cerebral performance category; PAI: pulmonary artery injury

Table 2: Summary of non-iatrogenic injury of the pulmonary artery since 1990

Total		**50 cases**
Age, years	Range	5-91
	Average	38.4
Gender	Male	40 (80%)
	Female	10 (20%)
Type of injury	Blunt	19 (38%)
	Penetrating	31 (62%)
Cause of injury	Gun	15 (30%): shot gun, air gun include
	Traffic accident	13 (32%)
	Knife	10 (20%)
	Others	9 (18%)
Type of PAI	Rupture	26 (52%)
	Pseudoaneurysm	17 (34%)
	Fistula	5 (10%)
	Dissection	2 (4%)
Symptom	Hemothorax	21 (42%)
	No specific	20 (40%)
	Tamponade	3 (6%)
	Others	3 (6%)
Treatment	Surgical sutures	22 (44%)
	Endovascular	10 (20%): include coil, stent and other materials
	Conservative	6 (12%)
	Other surgical maneuver	10 (20%)
	Other treatment	2 (4%)
Survival	Number and rate	46 (92%)

PAI: pulmonary artery injury

procedures are the most common cause of iatrogenic PAI rupture and pseudoaneurysm, with PA catheters being a particularly common culprit. Non-iatrogenic PAIs occur due to chest trauma but most chest trauma does not involve PAI. Penetrating injuries were more frequent than blunt injuries. The diagnosis was made based on intraoperative findings, enhanced CT or pulmonary arteriography. The main treatment method was surgery or an interventional approach. If PAI can be managed appropriately and promptly in patients without cardiac arrest, the patient may be saved.

DECLARATIONS

Authors' contributions

Designed the study, gathered data and wrote the manuscript: Yanagawa Y
Gave technical support, conceptual advice and edited the manuscript: Ishikawa K, Nagasawa H, Takeuchi I, Jitsuiki K, Ohsaka H, Omori K

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Conflicts of interest

The authors declare no conflicts of interest in association with this study.

Patient consent

Not applicable.

Ethics approval

This review article was approved by the review board of Juntendo Shizuoka Hospital, and all examinations were conducted according to the standards of good clinical practice and the Helsinki Declaration.

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