

Paradoxical Embolism in Orthopedic Patients a Brief-Review

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Abstract

The inter-atrial foramen allowing for intra-uterine arterial oxygenation should close after the birth. The foramen however remains open, unknown and undiagnosed unless an increase in the right ventricular pressure transfers emboli into the general oxygenated arterial system. Specific embolic syndromes exist in orthopedic surgery and will be briefly enumerated.

Keywords: Embolism; Paradoxical; Post-Traumatic; Post-Surgical

Introduction

The topic of the paradoxical embolus has preoccupied the authors as an interesting clinical syndrome and more so for the pathogenetic mechanism behind it.

How does a thrombus from the calves reach the brain? How does right sided venous cardiac non-oxygenated circulation mix with the left sided oxygenated blood? The pathology must be through an inter-atrial or inter-ventricular foramen or defect. Indeed, an embolism originating in the right sided circulation and shifting into the left-system would accurately be called Paradoxical.

With increased pressure in the pulmonary circulation and the right cardiac compartment, the embolic tissue, originating in the calves or less frequently in the pelvic veins are transferred to the left and dispersed through the arterial system. It is a rare event that potentially causes cerebral infarcts.

The embolic tissue could be blood thrombus, could be fat tissue displaced from the bone marrow, air bubbles emerging during a rapid surfacing of deep divers or could be displaced malignant tissue. It is of particular interest in orthopaedic surgery.

Pathogenesis

The Inter-atrial Foramen Ovale allows for intrauterine oxygenation and survival of the embryo. The foramen is redundant after the start of the newborn's pulmonary respiration and usually closes within one year. However, the Foramen was recorded in the literature to remain patent for some 27% to 35% of the population, being asymptomatic until there is an increase in pressure on the right sided pulmonary circulation, creating change in the gradient between the two atria [1-5].

The historical background takes us back centuries: The inter-atrial foramen was apparently known since Galen’s time in the second century CE and was discussed in more detail in Italian medical publications in the 16th century. It was known as “trou de Botal” in the French medical literature of the 19th Century.

Thrombosis was described in 1842 by Virchow, the great pathologist in Berlin, whereas the clinical syndrome of embolism was described by H. Wallman in 1859. The well-known clinical pathologist Julius Cohnheim in Berlin /Leipzig in 1872 defined the clinical aspect of embolism through the foramen ovale. It was further developed by Wilhelm Zhan in 1881 as “consequential embolism”. Amadee Rostand in Geneva in 1884 called it “*Embolie croisee*” and finalised a year later, again by Wilhelm Zahn as “*Paradoxical embolism*”, the title that remained permanent ever since [6-8].

The condition during the subsequent century advanced in a prophylactic and curative way, but with limited success. At present the diagnosis is based on saphenous and tibial vein ultrasound testing, with Trans-oesophageal Echocardiogram identification of the cardiac anomaly and bubble inflation to prove pathology [9-12].



Figure 1: Patent foramen ovale (arrow showing inter-atrial communication).

Once diagnosed, in the presence of cranial symptoms, the curative treatment is thrombolysis (if not contraindicated), insertion of intra-cava filter, and/or aspiration of the thrombus.

Identification of cranial circulation with CT Angiogram would allow for a therapeutic embolectomy. In a recent case, we described a cerebral embolism after a long-haul trans-Atlantic flight, with venous thrombosis in both calves [1].

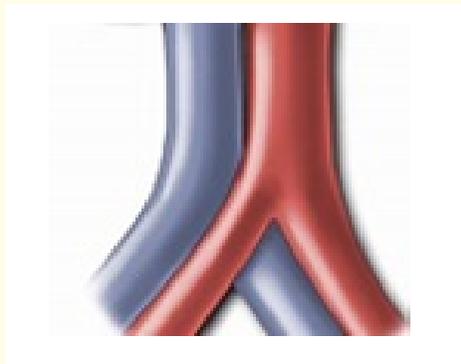
Paradoxical embolism reported in orthopaedic surgery: Deep vein thrombosis in legs is frequently leading to pulmonary embolism following immobilisation in multi-trauma patients with or without plaster/splint restrictions in mobility. It also occurs after recirculation from tourniquet application during orthopaedic surgery. Prophylactic treatment is with anti-coagulants and early postoperative mobilisation.

Case studies were published after bone surgery or trauma in:

- a) **Calf area:** Post-tibial osteotomy for osteoarthritis or following uni-or bi-lateral total knee prosthetic replacement [12-18].

- b) **Thigh area:** Post femoral lengthening procedures, in hip prosthesis or in revision hip surgery. It is during or soon after surgery that intramedullary fat, compressed by nail insertion in bony canal is dispersing fat into the veins, the thrombus reaching the lungs and the resulting increased gradient is shunting clots into the left and into the systemic arteries. Arterial embolization will reach to the cerebral and cerebellar arteries, to the subclavian arteries (with neurological defect in upper limbs), or to arterial femoral and of coronary arteries [19-24].
- c) **Spinal surgery:** Seemed to have had the most embolic events: in vertebroplasty for compression fractures resulting in thrombotic, in fat, and cement embolization. Of interest is the reported extensive laminectomies producing air embolism once operated in a sitting position [25-28].

Iliac vein pathology: Various iliac vein pathologies were reported, all leading to thrombosis: Such is the publication of paradoxical embolism resulting from a May-Thurner anomaly, with iliac arteries being placed in front, rather than behind the iliac veins, compressing and leading to left iliac vein thrombosis.



Picture 1: Anatomical design of anomaly, Iliac artery anterior to the veins.

Rarely, a reversal of thrombosis was published, namely within the right iliac vein. Of similar, if not identical detail, was the reported repairs of traumatic perforations of iliac vessels, with secondary thrombotic events [29,30].

Paradoxical embolism was described in various other clinical conditions such as resulting from resurfacing from deep water diving [31], and in embolism of malignant tissues from ovarian and prostate cancer, being even of greater interest [32,33].

Conclusion

The mechanism in all the presented types is identical, but the resulting pathology is different. In case of thrombus the pathology is an ischemic event, leading to anoxic tissue (brain, cardiac etc). In the case of bone and cement particles the effect might be toxic or occlusive.

The fat embolism is mainly a damage to the lung alveolar surface. The pathology in fatty cerebral embolism is detectable with fMRI, is resolved and rarely leading to tissue damage, but might have a cognitive impact [7,34-36]. The need for a pre-operative closure of PFO, remains an unsolved question.

Despite the high frequency of persistent Patent Foramen Ovale, there are relatively few published cases of embolism, most likely many remained un-diagnosed.

Bibliography

1. Weisz GM and Haber R. "Cerebral Infarct in a Long-Haul Traveller, From a Deep Vein Thrombosis, an Unusual Presentation, In a Person with Patent Foramen Ovale. A Special Case of Paradoxical Embolism". *Archives of Health Science* 5.1 (2021): 1-6.
2. Lechat P, et al. "Prevalence of patent foramen ovale in young patients with Stroke". *The New England Journal of Medicine* 318 (1988): 1148-1152.
3. Elliot G B. "Diagnosis of Paradoxical Embolism". *Canadian Medical Association Journal* 86 (1962): 292.
4. Kasner S C and Messe S R. "Is Patent Foramen Ovale a Risk Factor for Perioperative Stroke?" *JAMA: The Journal of the American Medical Association* 319.5 (2018): 446-447.
5. Johnson BI. "Paradoxical Embolism". *Journal of Clinical Pathology* 4 (1951): 316-321.
6. Cohnheim J F. "Thrombose und Embolie". *Vorlesungen fur Allgemeine Pathology* 1 (1877): 134.
7. Benaroyo L. "Contribution of Friedrich Wilhelm Zahn". Google Scholar (1991).
8. Rostan Amadee. "Contribution a l'etude de L'EMBOLIE CROISSE: Geneve". Rivera and Dubois (1884).
9. Della Valle C J, et al. "Paradoxical cerebral embolism complicating a major orthopaedic operation". *Journal of Bone and Joint Surgery* 81.1 (1999): 108-110.
10. Pell ACH, et al. "Fulminating Fat Embolism Caused by Paradoxical Embolism". *The New England Journal of Medicine* 329 (1993): 926-929.
11. Dive AM, et al. "Paradoxical Cerebral Fat Embolism: Case Reports". *Anesthes* 96.4 (2002): 1029-1031.
12. Steiger BW, et al. "Myocardial infarction due to paradoxical embolism". *The American Journal of Medicine* 37.6 (1969): 995-998.
13. Weiss S J, et al. "Fatal Paradoxical Embolization during Bilateral Knee Arthroplasty". *Case Reports in Anesthesiology* 84.3 (1996): 721-723.
14. Lin SY, et al. "Pulmonary and Paradoxical embolism after total knee replacement". *Acta anaesthesiologica Sinica* 34.2 (1996): 103-107.
15. Tangsataphor S. "Paradoxical embolism in bilateral total knee arthroplasty. Case reports". *Journal of the Medical Association of Thailand* 92.10 (2009): 1387-1392.
16. Hill B W, et al. "Paradoxical Cerebral Embolism After Total Knee Arthroplasty". *Orthopaedics* 35.11 (2012).
17. Miyake T Obayashi O, et al. "Paradoxical Embolization of the Bilateral Subclavian arteries after high tibial osteotomy". *Journal of the American Academy of Orthopaedic Surgeons: Global Research and Reviews* 3.8 (2019).
18. Ogino Y, et al. "Cerebral infarction after deflation of a pneumatic tourniquet during total knee replacement". *Anesthesiology* 90.1 (1999): 297.
19. Narimatsu E, et al. "Severe paradoxical intracranial embolism and pulmonary emboli during hip hemiarthroplasty". *British Journal of Anaesthesia* 91.6 (2003): 911-913.

20. Piuzzi N S., *et al.* "Paradoxical Cerebral Embolism in Revision Hip Surgery". *Case Reports in Orthopedics* (2014).
21. Koessler MJ and Pitto RP. "Fat and bone marrow embolism in total hip arthroplasty". *Acta Orthopaedica Belgica* 67.2 (2001): 97-109.
22. Mallouppas M., *et al.* "An unusual complication of his surgery: paradoxical coronary embolism of foreign material as a cause of acute MI". *EuroIntervention* 11.6 (2015): 658-610.
23. Patel R., *et al.* "Intra-operative cerebral microembolisation during primary hybrid total hiparthroplasty compared to primary hip surfacing". *Acta Orthopaedica Belgica* 75.5 (2009): 671-677.
24. Marden FA and Putman CM. "Cement-embolic stroke associated with vertebroplasty". *American Journal of Neuroradiology* 29.10 (2008): 1986-1988.
25. Scroop R., *et al.* "Paradoxical Cerebral Arterial Embolization of Cement during Intraoperative Vertebroplasty". *American Journal of Neuroradiology* 23 (2002): 868-870.
26. Dang CP., *et al.* "Paradoxical air embolism from patent foramen ovale in scoliosis surgery 27.11 (2002): 1-5.
27. Hamada SR and Mantz J. "Patent Foramen Ovale, Bubble test, and Major Spine Surgery". *Anesthesiology* 113 (2010): 463-464.
28. Kalu S., *et al.* "May-Thurner syndrome: a case report and review of the literature". *Case Reports in Vascular Medicine* (2013): 5.
29. Elms C., *et al.* "Paradoxical embolism through PFO leading to stroke in a gunshot victim with IVS injury". *Journal of Surgical Case Reports* 11 (2018).
30. Wilmhust PT., *et al.* "Relation between interatrial shunts and decompression sickness in divers". *Lancet* (1989): 1302-1534.
31. Kamenar E and Burger PC. "Cerebral Fat Embolism: A Neuropathological study of a Microembolic State". *Stroke* 11.5 (1980): 477-484.
32. Wada Y., *et al.* "Paradoxical cerebral embolism as an initialsymptom in a patient with ovarian cancer". *Journal of Stroke and Cerebrovascular Diseases* 16.2 (2007): 88-90.
33. Rigatelli G., *et al.* "Patent foramen ovale as a preferential mechanism for increasing likelihood of brain tumour metastasis". *American Journal of Cardiovascular Disease* 2.1 (2012): 29-33.
34. Weisz, GM., *et al.* "Fat Embolism". *Chest* 59.5 (1971): 511-516.
35. Weisz, GM., *et al.* "Post-Traumatic Fat Embolism in Children". *The Journal of Trauma* 13.6 (1973): 529-534.
36. Weisz GM. "Fat Embolism". *Current Problems in Surgery* 11 (1974): 1-54.

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