Original Article

This article is accompanied by an invited commentary by Prof. Howard Barkan

Epidural catheterization in cardiac surgery: The 2012 risk assessment

Thomas M. Hemmerling, Shantale Cyr, Nora Terrasini

Department of Anesthesiology, McGill University, Montreal, Canada and University of Pisa, Pisa, Italy

ABSTRACT

Aims and Objectives: The risk assessment of epidural hematoma due to catheter placement in patients undergoing cardiac surgery is essential since its benefits have to be weighed against risks, such as the risk of paraplegia. We determined the risk of the catheter-related epidural hematoma in cardiac surgery based on the cases reported in the literature up to September 2012. **Materials and Methods:** We included all reported cases of epidural catheter placement for cardiac surgery in web and in literature from 1966 to September 2012. Risks of other medical and non-medical activities were retrieved from recent reviews or national statistical reports. **Results:** Based on our analysis the risk of catheter-related epidural hematoma is 1 in 5493 with a 95% confidence interval (CI) of 1/970-1/31114. The risk of catheter-related epidural hematoma in cardiac surgery is similar to the risk in the general surgery population at 1 in 6,628 (95% CI 1/1,170-1/37,552). **Conclusions:** The present risk calculation does not justify not offering epidural analgesia as part of a multimodal analgesia protocol in cardiac surgery.

Received: 05-11-12
Accepted: 12-03-13

Key words: Epidural anesthesia, Epidural catheter, Epidural hematoma, High thoracic anesthesia, Risk assessment

INTRODUCTION

The risk-benefit ratio of medical procedures needs to be known in order to make the best choice in routine clinical practice. In cardiac surgery, epidural analgesia has been performed for many years;[1] however, its use is often limited by the fear of an increased risk of epidural hematoma because of ongoing and intraoperative anticoagulation therapy. Since epidural catheterization is a controversial technique and a strongly debated practice, it is crucial to update the risk benefit-ratio of epidural catheterization in the cardiac surgery. In a recent review, Royse[2] describes the benefits and risks related to high thoracic epidural analgesia and concludes that "epidural use in cardiac surgery is no more dangerous than in non-cardiac surgery." In 2007, Bracco and Hemmerling determined the risk of catheter-related epidural hematoma in cardiac surgery, searching databases from 1966 to March 2007.[3] The calculated risk was 1 epidural hematoma for 12000 epidural catheterization. The aim of this article is to update the risk of catheter-related epidural hematoma in the cardiac surgery using the databases from 1966 to September 2012.

MATERIALS AND METHODS

Risk assessment was calculated as follows: The number of epidural hematoma cases/number of epidural catheter placements for cardiac surgery as described in the literature. Medline, SciSearch, Embase, Google and Google Scholar were searched to select publications presenting patients who received epidural anesthesia/analgesia while undergoing cardiac surgery. The search criteria were: ([epidural anesthesia] OR [epidural catheter] OR [loco-regional anesthesia] OR [epidural) AND ([cardiac surgery] OR [coronary artery bypass grafting] OR [aortic valve surgery] OR [mitral valve surgery]), without any restrictions for language or type of study. Databases were explored from 1966 to September 2012: The authors read titles and abstracts of retrieved articles (around 3000), and full paper copy were obtained for all studies not eliminated for irrelevance to

Access this article online

Website: www.annals.in

PMID: 23816670

DOI: 10.4103/0971-9784.114237

Quick Response Code:

Address for correspondence: Prof. Thomas M. Hemmerling, Montreal General Hospital, C 10-153, 1650 Cedar Avenue, Montreal, H3G 1A4, Canada.
E-mail: thomas.hemmerling@mcgill.ca

the subject. The compiled publication list includes: Conference abstracts, randomized control trials, retrospective and prospective studies, and meta-analysis. The number of patients undergoing cardiac surgery who received epidural catheterization was retrieved; attention was paid to not count patients twice. After that, the total number of cases (which represents the denominator of our function) was calculated summing cases from 1966 to September 2012 (16,477 patients). The numerator was calculated adding cases of epidural hematoma after epidural catheterization in cardiac surgery, occurred from 1966 to 2012 (3 cases). The risk of catheter-related epidural hematoma was compared with several different risks, such as: The risk of catheter-related epidural hematoma in non-cardiac surgery, the risk of breast or prostate cancer, and the risk of road traffic injury. The percentages of risk used for comparison were extrapolated from the large trials, meta-analysis or national statistics reports. The Wilson method was used to calculate 95% two-sided confidence interval (CI) of a single proportion.[4] The comparison between 2 proportions was carried out using the same method.[5]

RESULTS

From 1966 to September 2012, 16,477 patients undergoing cardiac surgery were found who received only epidural or epidural plus general anesthesia (GA). The risk of catheter-related epidural hematoma was 3 cases out of 16,477 patients, or 1/5,493, with a 95% CI of 1/970-1/31,114. This population also included some pediatric patients. The type of surgery and the number of the patients derived from articles from April 2007 to September 2012 are shown in Table 1. Previous articles were presented in the study by Bracco and Hemmerling.[3] Only two cases of catheter-related epidural hematoma are described in the literature from April 2007 to September 2012. The 1st one occurred in 2010 and reported by the UK Medical Protection Society.[6] A 70-year-old woman underwent coronary artery bypass grafting revision surgery 6 years after she received a triple coronary artery bypass grafting. An epidural catheter was placed on the day of surgery without incident and general anesthesia was induced. In the morning of the day after surgery, the patient showed neurological symptoms noticed by a nurse. She underwent a neurological examination revealing an intense motor and sensory deficit at the T6 level bilaterally; then hours later, her spine was examined using a Computed Tomography scan. A large hematoma was found in the epidural space; an emergency laminectomy and evacuation of hematoma were performed in the evening, about 12 h after the 1st symptom appeared. The patient remained paraplegic. The 2nd case of catheter-related epidural hematoma happened in 2011.[11] On the day of surgery, after induction of general anesthesia, an epidural catheter was placed. The patient, a 55-year-old man scheduled for the mitral valve replacement and tricuspid valvuloplasty, had stopped warfarin 7 days before surgery. Pre-operative blood exam revealed a normal coagulation profile and normal platelet count. At the end of surgery, International Normalized Ratio (INR) and Activated Partial Thromboplastin Time (aPTT) were 1.52 and 42.2 s, respectively, and his platelet count was 77,000/mm^3. A flaccid paraplegia appeared 16 h after the end of surgery; at that time, his coagulation profile was still altered (aPTT 53.3 s, INR 1.30). An emergency magnetic resonance imaging showed an epidural hematoma at the T5-T6 level, a laminectomy, within 6 h since the onset of the symptoms was performed to remove the hematoma. This patient had a good overall recovery and presented only slight dysuria 6 months after laminectomy. The third case of catheter-related epidural hematoma was reported earlier by Bracco and Hemmerling; it occurred in 1995 and was reported in 2004.[76] The epidural catheter was placed on the day of surgery in a 60-year-old man who underwent coronary artery bypass grafting surgery. He had no health problems other than the ischemic heart disease. The epidural catheter placement at T12/L1 was uneventful as well as the surgery; heparinization was reversed, and the patient received 4 units of fresh frozen plasma and 6 units of platelets The morning after surgery around 7 am, a nurse noticed that the man could move his arms but not his legs, and it was ascribed to the sleepy state of the patient. Around 11 am, the patient could not move his legs, even though he was extubated since 3 h; the catheter was removed. At 16 h, magnetic resonance imaging (MRI) scan revealed a spinal hematoma from T5 to T10, and 4 h later it was evacuated through a laminectomy. The surgery started around 13 h after the first symptom of neurological deficits were noticed. The patient was paralyzed in his legs, and he did not recover after surgery. Several cases of neurological complications occurring in patients with an epidural catheter placed for cardiac surgery are described in the literature. Arora *et al.*, reported a case of pneumocephalus after epidural anesthesia.[9] The patient, a 68-year-old hypertensive, diabetic, and an obese male was admitted for coronary artery bypass

Table 1: The articles included for the current risk assessment. Only articles from April 2007 to September 2012 are included. The previous articles were published earlier by Bracco and Hemmerling[3]

First author	Year	Journal	Surgery	Epidural
No authors listed[6]	2010	Medical protection society, UK. advice and publications/case report	CABG (epidural hematoma)	1
No authors listed[7]	2011	Anesteziol Reanimatol	CABG	40
Amat-Santos[8]	2012	Heart	Transapical transcatheter aortic valve implantation	74
Arora[9]	2012	Ann Card Anaesth	CABG (seizures and headache)	1
Bakhtiary[10]	2007	Thorac Cardiovasc Surg	OPCAB	66
Bang[11]	2011	Korean J Anesthesiol	Mitral valve replacement and tricuspid valve annular plasty (epidural hematoma at the T5-6 level)	1
Bottio[12]	2007	Heart Valve Dis	Heart valve surgery	50
Bracco[13]	2007	Heart Surg Forum	Different types of cardiac surgery	506
Caputo[14]	2009	Ann Thorac Surg	OPCAB	36
Caputo[15]	2011	Anesthesiology	OPCAB	109
Chakravarthy[16]	2010	Cardiothorac Vasc Anesth	Ostium secundum atrial septal defect	1
Connelly[17]	2011	Heart, Lung and Circulation	CABG	10
Crescenzi[18]	2008	Eur J Anaesthesiol	Mitral valve replacement	1
Crescenzi[19]	2009	Cardiothorac Vasc Anesth	CABG	46
Del Giglio[20]	2009	Innovations: Technology and Techniques in Cardiothoracic and Vascular Surgery	Minimally Invasive Coronary Surgery and Percutaneous Coronary Revascularization	2
Del Giglio[21]	2009	Interact Cardiovasc Thorac Surg,	Hybrid revascularization	2
El-Morsy[22]	2012	Saudi J Anaesth	CABG	25
Gangopadhyay[23]	2010	Indian J Anaesth	On pump-open heart surgery	72
Greisen[24]	2012	Acta Anaesthesiol Scand	CABG with or without aortic valve replacement	42
Heijmans[25]	2007	Cardiothorac Vasc Anesth	Coronary artery bypass surgery	15
Hosain[26]	2009	Abstract 7 of the 55th Annual Conference of IACTS	Awake CABG	26
Ikeda[27]	2008	Masui 57 (8): 999-1001	Awake CABG	2
Jakobsen[28]	2007	Europ J Anaesth	CABG	10
Jakobsen[29]	2012	Cardiothorac Vasc Anesth	CABG with or without aortic valve replacement.	30
Kaddoum[30]	2008	Middle East J Anesthesiol	CABG	1
Kilickan[31]	2008	Cardiovasc Surg	CABG	30
Kirov[32]	2011	Anesthesiol	OPCAB	62
Knapik[33]	2008	Ann Thorac Surg	Awake cardiac surgery	1
Kundu[34]	2008	Bangladesh Coll Phys Surg	OPCAB	20
Kurtoglu[35]	2009	Anadolu Kardiyol Derg	MIDCAB surgery	34
Lenkutis[36]	2009	Perfusion	CABG with CPB	30
Liang[37]	2012	Anesth	OPCAB	64
Loponen[38]	2008	Scandinavian Cardiovascular Journal	On-pump and off-pump CABG	78
Mehta[39]	2008	Ann Card Anaesth	Robotic-assisted CABG	19
Mehta[40]	2010	Ann Card Anaesth	OPCAB	31
Monaco[41]	2012	Ann Card Anaesth	Mitral valve surgery	30
Mukherjee[42]	2009	Innovations: Technology and Techniques in Cardiothoracic and Vascular Surgery	TA-TAVI	7
Mukherjee[43]	2009	Ann Thorac Surg	Transapical aortic valve implantation	1
Muneretto[44]	2007	Innovations: Technology and Techniques in Cardiothoracic and Vascular Surgery	Elective heart valve surgery	55
Nielsen[45]	2012	Cardiothorac Vasc Anesth	Elective heart valve surgery without aortic valve replacement	30
Noiseux[46]	2008	Anaesth	OPCAB	15
Olivier[47]	2007	Heart Surg Forum	Cardiac surgery	26
Olivier[48]	2009	Open Anesthesiology Journal	OPCAB	42
Onan[49]	2011	Cardiothorac Vasc Anesth	CABG	15
Ortega[50]	2011	CorSalud	Myocardial bypass surgery	20
Palomero Rodriguez[51]	2008	Minerva Anestesiol	CABG with CPB	10
Petridis[52]	2012	Interact Cardiovasc Thorac Surg	Awake transapical aortic valve implantation	1
Petrovski[53]	2007	European Journal of Anaesthesiology	OPCAB	10

Contd...

Table 1: Contd...

First author	Year	Journal	Surgery	Epidural
Petrovski[54]	2007	European Journal of Anaesthesiology	Open heart surgery	75
Petrovski[55]	2007	European Journal of Anaesthesiology	Surgery for ischemic dilatative cardiomyopathy	20
Picozzi[56]	2007	Acta Anaesthesiol Scand	Mitral valve replacement	1
Porizka[57]	2011	Anesth	Elective on-pump cardiac surgery	32
Porizka[58]	2011	Eur J Cardiothorac Surg	On-pump cardiac surgery	30
Puja[59]	2009	Abstract 1 of the 55th Annual Conference of IACTS, May 2009	OPCAB	2
Ram Rao[60]	2012	Indian Journal of Thoracic and Cardiovascular Surgery	Awake cardiac surgery	30
Rieke[61]	2011	Anestezjologia I Ratownictwo	CABG	10
Royse[62]	2007	Anaesthesia	CABG	10
Salvi[63]	2007	Cardiothorac Vasc Anesth	CABG	476
Sendasgupta[64]	2009	Ann Card Anaesth	Pediatric patients undergoing open heart surgery (caudal block)	15
Sener[65]	2010	Exp Clin Endocrinol Diabetes	Surgery with CPB	18
Sharma[66]	2010	Ann Card Anaesth	OPCAB	30
Suga[67]	2010	Masui	OPCAB	1
Suryaprakash[68]	2011	Ann Card Anaesth	OPCAB	25
Svircevic[69]	2011	Anesthesiology	Cardiac surgery	303
Tenenbein[70]	2008	Can J Anaesth	CABG	25
Thammasitboo[71]	2010	Paediatr Anaesth	Surgery for congenital heart defects	733
Torre[72]	2007	The Heart Surgery Forum	Surgical correction of multiple valve disease	1
Watanabe[73]	2011	Innovations	Awake OPCAB	55
Watanabe[74]	2011	Eur J Cardiothorac Surg	Awake OPCAB	72
Weiner[75]	2012	Cardiothorac Vasc Anesth	Surgery for congenital heart disease using CPB	714

CABG: Coronary artery bypass surgery, TA: Transapical, TAVI: Transcatheter aortic valve implantation, OPCAB: Off-pump coronary artery bypass, MIDCAB: Minimally invasive direct coronary artery bypass, CPB: Cardiopulmonary bypass

surgery. After uneventful epidural catheter insertion, the test dose was administered (2 ml of 2% lidocaine). Immediately, the patient reported severe headache, and then generalized tonic-clonic seizures developed. The patient regained consciousness 10 min later after control of seizures. The MRI showed air in the basal cisterns and subarachnoid spaces. The patient refused to undergo surgery and underwent successful coronary angioplasty 2 days later. The authors concluded that the complications were due to the puncture of the dura-mater.

The risk of catheter-related epidural hematoma in cardiac surgery is comparable to the risk of epidural hematoma after use of epidural catheters for general surgery.[77,78] In Germany, Volk *et al.*, estimated an incidence of epidural hematoma of 1:6,628 in general surgical population from 2008 to 2009.[78] For this report, a relative risk reduction of 17% favoring general surgery (not significant) was calculated between the risk of epidural hematoma after catheterization in the cardiac surgery (1/5,493) and in general surgery (1/6,628).The mortality for heart disease in the United States is 10 times higher than the risk of epidural hematoma after epidural anesthesia/analgesia for cardiac surgery.[79] The risk of catheter-related epidural hematoma in cardiac surgery is 100 times lower than the risk of acute renal failure after coronary artery bypass grafting surgery,[80] and the risk of sternal wound infection.[81] The risk of catheter-related epidural hematoma in cardiac surgery is 1,000 times lower than the frequency of prescribing errors in hospitals (errors/admissions).[82] Patients undergoing cardiac surgery with an epidural catheter in place have a risk to develop an epidural hematoma comparable to the risk of women developing breast cancer (women/year),[83] or prostate cancer (men/year),[83] and to the risk of dying by car traffic accident (deaths/population) [Figure 1].[84]

DISCUSSION

Knowing the risk related to medical procedures is extremely beneficial in the clinical practice; it permits to correctly evaluate the risk-benefit ratio and to obtain an informed consent before performing the procedures. Two recent meta-analyses have shown that the use of epidural analgesia/anesthesia in patients undergoing cardiac surgery improves the outcome by decreasing the incidence of acute renal failure, the incidence of post-operative supraventricular arrhythmias, the

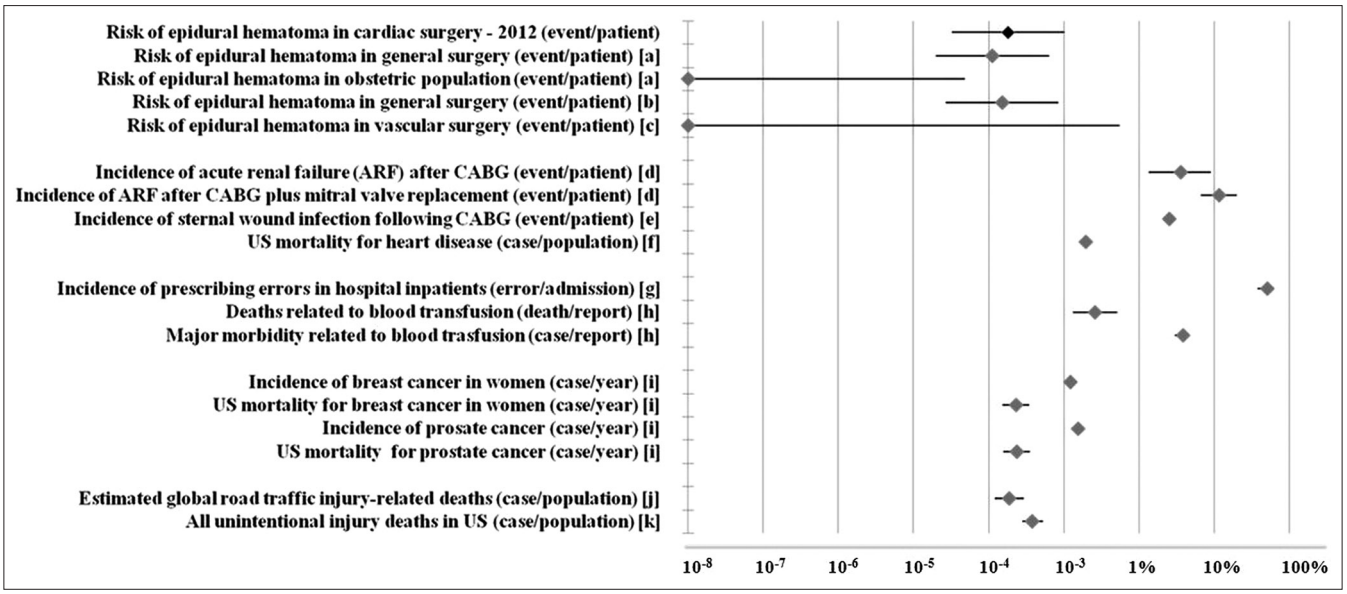

Figure 1: Risk comparison. Risk of catheter-related epidural hematoma of some medical complications of some nonmedical activities. Risk is expressed as proportion (diamond) and its 2-sided 95% confidence interval (lines). (a) Data from [Bateman, 2012, Anesth Analg, Epub ahead of print]. (b) Data from (Volk, 2012, Eur J Anaesthesiol 29 (4): 170-176). (c) Data from (Osta, 2010, Br J Anaesth 104 (4): 429-432). (d) Data from (Martinelli, 2009, Ren Fail 31 (8): 633-640). (e) Data from (Lu, 2003, European Journal of Cardio-Thoracic Surgery 23 (6): 943-949). (f) Data form (Heart Disease-Centers for Disease Control and Prevention, 2009, http://www.cdc.gov/nchs/fastats/heart.htm). (g) Data from (Lewis, 2009, Drug Saf 32 (5): 379-389). (h) Data from (The Serious Hazards of Transfusion [SHOT] Steering Group, 2012, http://www.shotuk.org/wp-content/uploads/2012/07/SHOT-Summary_FinalWebVersion 2012_06_261.pdf). (i) Data from [US National Cancer Institute, 2009, http://seer.cancer.gov/statfacts/]. (j) Data from (WHO-World report on road traffic injury prevention, 2002, http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/chapter 2.pdf). (k) Data from (Unintentional injury deaths, 2009, http://www.cdc.gov/nchs/fastats/acc-inj.htm)

time on mechanical ventilation, and respiratory complications.[85,86] The composite endpoint of mortality and myocardial infarction are decreased by the use of epidural anesthesia in cardiac surgery.[86] Epidural anesthesia/analgesia can be an vital intervention in a multimodal strategy.

Awake cardiac surgery is a new minimally invasive anesthesia technique, and it might be an option for high-risk patients with severe lung disease; avoiding intubation and mechanical ventilation might be able to reduce the risk of morbidity and mortality.[20,33,42,44,52,53] The present article demonstrates that the risk of catheter-related epidural hematoma in cardiac surgery is not zero; however, a risk that is comparable to the risk of dying in a car accident,[87] which is a hazard commonly accepted [Figure 1].

As previously studied by Ho *et al*., we decided to consider all studies about 'epidural in cardiac surgery, even if no reports about epidural hematoma and/or neurological injuries were present.[88] In 2006, Ruppen *et al*.,[89] calculated the incidence of epidural hematoma and neurological injury in patients with epidural anesthesia/analgesia undergoing cardiac surgery, selecting 12 studies from1966 to February 2005, which met their search criteria. Only articles reporting at least 100 cardiovascular or thoracic surgery patients and numerical data about hematoma and neurological injuries were selected for the meta-analysis. They found 4971, 4108, and 5026 cases of cardiac, thoracic, and vascular surgery, respectively. No cases of epidural hematoma were found, therefore, according to Hanley and Lippman-Hand's mathematical model, the maximum risk of epidural hematoma in cardiac surgery was determined as 1 out of 1700 (0.06%). In the same year, Ruppen *et al*.,[90] also described the incidence of epidural hematoma, infection and neurologic injury in obstetric patients with epidural analgesia/anesthesia, searching articles from 1966 to 2005; all the articles including at least 200 obstetric patients and numerical data about epidural catheterization related adverse outcomes were included in the study. A risk of 1 epidural hematoma in 183,000 cases was found (0.0005%). Christie and McCabe described 3 cases of epidural hematoma in 8,100 patients (0.04%), who underwent significant surgery between January 2000 and December 2005 in their hospital.[91] One out of 3 hematoma was due to coagulopathy caused by a dose of low molecular weight heparin 9 hours after a complicated insertion of epidural catheter. Authors suggested that adverse neurological outcome and severity of the neurological deficit after epidural hematoma was related to diagnostic delays. The increased risk compared to the 2007 assessment by Bracco and Hemmerling,[3] might be due to a decrease in the number of cases we used to determine the

denominator. Since epidural analgesia/anesthesia is no longer a novelty in cardiac anesthesia, less case studies or series are reported; the number of actual thoracic epidurals may be much higher after cardiac surgery as not all routine epidurals are reported and therefore, the actual risk may be even lower.

In the literature, several cases of idiopathic epidural hematoma are reported.[92] Cases of spontaneous epidural hematoma without an epidural catheter after cardiac surgery are also described.[93-96] Hayashi *et al.*, reported a 71-year-old women, who underwent mitral valvoplasty with CPB.[95] Surgery lasted around 4 h uneventfully, and she was not previously treated with any anticoagulant therapy. One hour after surgery, paraplegia was noted, an epidural hematoma compressing the spinal cord at the C7-T4 level was revealed on MR imaging. A conservative approach was chosen because the paraplegia was not progressive. The authors stated that the epidural hematoma etiology was not evident. The woman had a good overall outcome.

There are several considerations of using an epidural technique in cardiac surgery which should be mentioned despite no scientific risk assessment available in the literature. An epidural technique necessitates a considerable effort in establishing an infrastructure, which allows safe conduct of epidural analgesia. If the epidural is placed the day before surgery, then substantial logistical issues need to be resolved: When exactly is the catheter inserted, how long and where should the patient be admitted and monitored before being transferred to the general cardiac surgery ward. If the epidural catheter is inserted on the day of surgery, this adds time to the induction time; however, this is an issue, which is not specific for epidural techniques in cardiac surgery only and therefore, not different from the use of epidural techniques in general surgery. Since the insertion of an epidural catheter for cardiac surgery should be reserved to expert hands, the time added for insertion should be within the range of 5-15 min. There needs to be a "culture" where the potential of case cancellation due to a bloody tap is accepted as a rare, but unavoidable complication. The user, together with all health-care providers, should have a protocol for this rare complication in place: Cancellation with venous tap or arterial tap only? (The differentiation is easy by drawing blood for a blood gas). Based on the literature and the senior author's own experience, the probability of a bloody tap is approximately 1 in 1000 cases – however, there is no scientific data published. More and more patients are on aggressive antiplatelet therapy: Diligent protocoling of the type and dosage of antiplatelet drugs before surgery and their cessation is important for safe insertion of an epidural catheter in cardiac surgery. Even more important is the establishment of a protocol for post-operative anticoagulation especially in valve surgery. The physiological benefits of thoracic epidural analgesia are greatest in the first 48 h after surgery. They include early extubation, reduced respiratory complications and cardiac dysrhythmias, as well as better analgesia.[97] Therefore, it is important to have 24-48 h of post-operative period before the start of anticoagulant treatment. The removal of the epidural catheter needs to be preceded by a normal coagulation profile. Protocols need to be in place: What to do when an abnormal coagulation profile is detected with an epidural catheter in place? In addition, there needs to be a diligent protocol for repetitive – short intervals of neurological assessment after surgery of these patients to detect possible neurological complications early enough. The combination of TEA and early or immediate extubation are the safest choice to allow neurological diagnosis. However, this is true for any epidural technique in any patient for any surgery: If the patient stays intubated after surgery, then neurological deficits might be masked by the level of sedation of the patient to respond to commands for neurological assessment. Performing epidural techniques in cardiac surgery in a center with no immediate access to MRI scanning of the spine cannot be recommended. From the moment the clinical diagnosis or suspicion is raised, there should be no delay to confirm the diagnosis via MRI. The literature has shown that recovery from epidural hematoma in the cardiac surgery can be complete only if the established time interval between detection and surgery (approximately within 8 h) is respected.

Limitations of the current risk analysis are related to our decision of not considering differences among the studies we used as source. Different times of catheter placement, different perioperative heparinization protocols, and different puncture levels are not taken into account. It would be impossible because of the limited number of patients undergoing cardiac surgery with epidural analgesia/anesthesia and even lesser number[3] of cases of epidural hematoma described in the literature.

In conclusion, evaluating the risk-benefit ratio of using thoracic epidural anesthesia in cardiac surgery shows that the risk of catheter-related epidural hematoma is 1/5,493, with a 95% CI of 1/970-1/31,114.

REFERENCES

1. Robinson RJ, Brister S, Jones E, Quigly M. Epidural meperidine analgesia after cardiac surgery. Can Anaesth Soc J 1986;33:550-5.
2. Royse CF. High thoracic epidural anaesthesia for cardiac surgery. Curr Opin Anaesthesiol 2009;22:84-7.
3. Bracco D, Hemmerling T. Epidural analgesia in cardiac surgery: An updated risk assessment. Heart Surg Forum 2007;10:E334-7.
4. Newcombe RG. Two-sided confidence intervals for the single proportion: Comparison of seven methods. Stat Med 1998;17:857-72.
5. Newcombe RG. Interval estimation for the difference between independent proportions: Comparison of eleven methods. Stat Med 1998;17:873-90.
6. UK Medical Protection Society/Advice and publications/Case reports/ Vol. 18 no. 3-September 2010/A bloody epidural. Available from: http://www.medicalprotection.org/uk/case-reports-september-2010/a-bloody-epidural. [Last cited on 2012 Sep 21].
7. Combined inhalation and epidural anesthesia, during aortocoronary bypass surgery on beating heart. Anesteziol Reanimatol 2011;6:8-12.
8. Amat-Santos IJ, Dumont E, Villeneuve J, Doyle D, Rheault M, Lavigne D, *et al*. Effect of thoracic epidural analgesia on clinical outcomes following transapical transcatheter aortic valve implantation. Heart 2012;98:1583-90.
9. Arora D, Mehta Y, Jain A, Trehan N. Headache and seizures after cervical epidural injection in a patient undergoing coronary artery bypass grafting. Ann Card Anaesth 2012;15:244-6.
10. Bakhtiary F, Therapidis P, Dzemali O, Ak K, Ackermann H, Meininger D, *et al*. Impact of high thoracic epidural anesthesia on incidence of perioperative atrial fibrillation in off-pump coronary bypass grafting: A prospective randomized study. J Thorac Cardiovasc Surg 2007;134:460-4.
11. Bang J, Kim JU, Lee YM, Joh J, An EH, Lee JY, *et al*. Spinal epidural hematoma related to an epidural catheter in a cardiac surgery patient: A case report. Korean J Anesthesiol 2011;61:524-7.
12. Bottio T, Bisleri G, Piccoli P, Negri A, Manzato A, Muneretto C. Heart valve surgery in a very high-risk population: A preliminary experience in awake patients. J Heart Valve Dis 2007;16:187-94.
13. Bracco D, Noiseux N, Dubois MJ, Prieto I, Basile F, Olivier JF, *et al*. Epidural anesthesia improves outcome and resource use in cardiac surgery: A single-center study of a 1293-patient cohort. Heart Surg Forum 2007;10:E449-58.
14. Caputo M, Alwair H, Rogers CA, Ginty M, Monk C, Tomkins S, *et al*. Myocardial, inflammatory, and stress responses in off-pump coronary artery bypass graft surgery with thoracic epidural anesthesia. Ann Thorac Surg 2009;87:1119-26.
15. Caputo M, Alwair H, Rogers CA, Pike K, Cohen A, Monk C, *et al*. Thoracic epidural anesthesia improves early outcomes in patients undergoing off-pump coronary artery bypass surgery: A prospective, randomized, controlled trial. Anesthesiology 2011;114:380-90.
16. Chakravarthy M, Mitra S, Muralimanohar V, Jawali V. Congenital pleuropericardial fistula complicating awake cardiac surgery. J Cardiothorac Vasc Anesth 2010;24:901-3.
17. Connelly KA, Royse C, Royse AG. Tissue Doppler Em and instantaneous end-diastolic stiffness: Validation against pressure-volume loops in patients undergoing coronary artery bypass surgery. Heart Lung Circ 2011;20:223-30.
18. Crescenzi G, Covello RD, Landoni G, De Luca M, Fracasso G, Melone M, *et al*. Thoracic epidural anaesthesia in valvular cardiac surgery. Eur J Anaesthesiol 2008;25:339-40.
19. Crescenzi G, Landoni G, Monaco F, Bignami E, De Luca M, Frau G, *et al*. Epidural anesthesia in elderly patients undergoing coronary artery bypass graft surgery. J Cardiothorac Vasc Anesth 2009;23:807-12.
20. Del Giglio M, Dell'Amore A, Calvi S, Sokolli H, Zuffi A, Lamarra M. Awake minimally invasive coronary surgery and percutaneous coronary revascularization: A new one day hybrid procedure. Innovations: Technology and techniques in cardiothoracic and vascular surgery. Innovations 2009;4:CR8.
21. Del Giglio M, Dell'Amore A, Zuffi A, Sokoli A. One-stage hybrid procedure: Association between awake minimally invasive surgical revascularization and percutaneous coronary intervention. Interact Cardiovasc Thorac Surg 2009;9:551-3.
22. El-Morsy GZ, El-Deeb A. The outcome of thoracic epidural anesthesia in elderly patients undergoing coronary artery bypass graft surgery. Saudi J Anaesth 2012;6:16-21.
23. Gangopadhyay S, Acharjee A, Nayak SK, Dawn S, Piplai G, Gupta K. Immediate extubation versus standard postoperative ventilation: Our experience in on pump open heart surgery. Indian J Anaesth 2010;54:525-30.
24. Greisen J, Nielsen DV, Sloth E, Jakobsen CJ. High thoracic epidural analgesia decreases stress hyperglycemia and insulin need in cardiac surgery patients. Acta Anaesthesiol Scand 2013;57:171-7.
25. Heijmans J, Fransen E, Buurman W, Maessen J, Roekaerts P. Comparison of the modulatory effects of four different fast-track anesthetic techniques on the inflammatory response to cardiac surgery with cardiopulmonary bypass. J Cardiothorac Vasc Anesth 2007;21:512-8.
26. Hosain SN, Maruf F, Hassan K, Alam M, Rasheed H, Haque N. Ahsan K. Awake CABG and OPCAB: Safety and economic issues. Indian J Thorac Cardiovasc Surg 2009;25:147-61. (abstract 7)
27. Ikeda S, Kumano N, Arimori Y, Ono T, Saeki S. Anesthetic management of awake off-pump coronary artery bypass grafting (ACAB) with remifentanil and thoracic epidural anesthesia. Masui 2008;57:999-1001.
28. Jakobsen CJ, Kirkegaard H, Christiansen CL, Lorentzen AG, Severinsen IK, Sloth E. Epidural anaesthesia reduces NT-proBNP after cardiac surgery. Eur J Anaesthesiol 2007;24:O-18
29. Jakobsen CJ, Bhavsar R, Nielsen DV, Ryhammer PK, Sloth E, Greisen J. High thoracic epidural analgesia in cardiac surgery: Part 1-high thoracic epidural analgesia improves cardiac performance in cardiac surgery patients. J Cardiothorac Vasc Anesth 2012;26:1039-47.
30. Kaddoum RN, Yu J, Wang H, Chidiac EJ. Anesthesia management of a Jehovah's Witness patient with pheochromocytoma undergoing off pump coronary artery bypass graft surgery: A case report. Middle East J Anesthesiol 2008;19:1099-104.
31. Kiliçkan L, Yumuk Z, Bayindir O. The effect of combined preinduction thoracic epidural anaesthesia and glucocorticoid administration on perioperative interleukin-10 levels and hyperglycemia. A randomized controlled t rial. J Cardiovasc Surg (Torino) 2008;49:87-93.
32. Kirov MY, Eremeev AV, Smetkin AA, Bjertnaes LJ. Epidural anesthesia and postoperative analgesia with ropivacaine and fentanyl in off-pump coronary artery bypass grafting: A randomized, controlled study. BMC Anesthesiol 2011;11:17.
33. Knapik P, Przybylski R, Nadziakiewicz P, Zembala M. Awake heart valve surgery in a patient with severe pulmonary disease. Ann Thorac Surg 2008;86:293-5.
34. Kundu RK, Beg AK, Hossain S, Haque N, Mahafuddoza M, Chowdhury AY. Comparative study of haemodynamic status and arrhythmia between combined epidural with general anaesthesia and general anaesthesia alone in off-pump coronary artery bypass (opcab) surgery. J Bangladesh Coll Phys Surg 2008;26:116-20.
35. Kurtoğlu M, Ateş S, Bakkaloğlu B, Beşbaş S, Duvan I, Akdaş H, *et al*. Epidural anesthesia versus general anesthesia in patients undergoing minimally invasive direct coronary artery bypass surgery. Anadolu Kardiyol Derg 2009;9:54-8.
36. Lenkutis T, Benetis R, Sirvinskas E, Raliene L, Judickaite L. Effects of epidural anesthesia on intrathoracic blood volume and extravascular lung water during on-pump cardiac surgery. Perfusion 2009;24:243-8.
37. Liang Y, Chu H, Zhen H, Wang S, Gu M. A prospective randomized study of intraoperative thoracic epidural analgesia in off-pump coronary artery bypass surgery. J Anesth 2012;26:393-9.
38. Loponen P, Luther M, Wistbacka JO, Nissinen J, Sintonen H, Huhtala H, *et al*. Postoperative delirium and health related quality of life after coronary artery bypass grafting. Scand Cardiovasc J 2008;42:337-44.
39. Mehta Y, Arora D, Sharma KK, Mishra Y, Wasir H, Trehan N. Comparison of continuous thoracic epidural and paravertebral block for postoperative analgesia after robotic-assisted coronary artery bypass surgery. Ann Card Anaesth 2008;11:91-6.

40. Mehta Y, Vats M, Sharma M, Arora R, Trehan N. Thoracic epidural analgesia for off-pump coronary artery bypass surgery in patients with chronic obstructive pulmonary disease. Ann Card Anaesth 2010;13:224-30.
41. Monaco F, Biselli C, De Luca M, Landoni G, Lembo R, Zangrillo A. Thoracic epidural anesthesia in elderly patients undergoing cardiac surgery for mitral regurgitation feasibility study. Ann Card Anaesth 2012;15:164-5.
42. Mukherjee C, Walther T, Borger MA, Kempfert J, Schuler G, Mohr FW, *et al*. Awake transapical aortic valve implantation using thoracic epidural anesthesia. Ann Thorac Surg. 2009;88:992-4.
43. Mukherjee C, Walther T, Borger MA, Kempfert J, Schuler G, Mohr FW, *et al*. Awake transapical aortic valve implantation using thoracic epidural anesthesia. Ann Thorac Surg 2009;88:992-4.
44. Bottio T, Bisleri G, Piccoli P, Negri A, Manzato A, Muneretto C. Heart valve surgery in a very high-risk population: A preliminary experience in awake patients. J Heart Valve Dis 2007;16:187-94.
45. Nielsen DV, Bhavsar R, Greisen J, Ryhammer PK, Sloth E, Jakobsen CJ. High thoracic epidural analgesia in cardiac surgery: Part 2-high thoracic epidural analgesia does not reduce time in or improve quality of recovery in the intensive care unit. J Cardiothorac Vasc Anesth 2012;26:1048-54.
46. Noiseux N, Prieto I, Bracco D, Basile F, Hemmerling T. Coronary artery bypass grafting in the awake patient combining high thoracic epidural and femoral nerve block: First series of 15 patients. Br J Anaesth 2008;100:184-9.
47. Olivier JF, Bracco D, Nguyen P, Le N, Noiseux N, Hemmerling T, *et al*. A novel approach for pain management in cardiac surgery via median sternotomy: Bilateral single-shot paravertebral blocks. Heart Surg Forum 2007;10:E357-62.
48. Olivier JF, Prieto I, Basile F, Hemmerling TM. Comparison of three different epidural solutions in cardiac surgery for stress protection. The Open Anesthesiology Journal, 2009, 3, 1-7
49. Onan IS, Onan B, Korkmaz AA, Oklu L, Kilickan L, Gonca S, *et al*. Effects of thoracic epidural anesthesia on flow and endothelium of internal thoracic artery in coronary *artery* bypass graft surgery. J Cardiothorac Vasc Anesth 2011;25:1063-70.
50. Ortega RH, Alfonso OG, Menéndez PA, Font IM, Rodríguez JM, Martínez JM, *et al*. Eficacia analgésica postoperatoria de la morfina epidural en la cirugía de revascularización miocárdica/postoperative analgesic efficacy of epidural morphine in myocardial bypass surgery. Cor Salud 2011;3:15-25.
51. Palomero Rodríguez MA, Suarez Gonzalo L, Villar Alvarez F, Varela Crespo C, Moreno Gomez Limon I, Criado Jimenez A. Thoracic epidural anesthesia decreases C-reactive protein levels in patients undergoing elective coronary artery bypass graft surgery with cardiopulmonary bypass. Minerva Anestesiol 2008;74:619-26.
52. Petridis FD, Savini C, Castelli A, Di Bartolomeo R. Awake transapical aortic valve implantation. Interact Cardiovasc Thorac Surg 2012;14:673-4.
53. Petrovski V, Anguseva T, Belostotskii V, Hristov N, Mitrev Z. Awake off pump coronary artery bypass surgery. Eur J Anaesthesiol 2007;24:8AP8-2.
54. Petrovski VE, Stoicovski T. Manailova N, Hristov Z, Mitrev Z. Epidural anesthesia in cardiac surgery. Eur J Anaesthesiol 2007;24:101. Abstract 8AP8-3.
55. Petrovski VE. Stoicovski D, Slavevski N, Hristov Z, Mitrev Z. High thoracic epidural anesthesia versus general anesthesia in surgery for ischemic dilatative cardiomyopathy. Eur J Anaesthesiol 2007;24:162. Abstract 12AP9-4.
56. Picozzi P, Lappa A, Menichetti A. Mitral valve replacement under thoracic epidural anesthesia in an awake patient suffering from systemic sclerosis. Acta Anaesthesiol Scand 2007;51:644.
57. Porizka M, Stritesky M, Semrad M, Dobias M, Dohnalova A. Postoperative outcome in awake, on-pump, cardiac surgery patients. J Anesth 2011;25:500-8.
58. Porizka M, Stritesky M, Semrad M, Dobias M, Dohnalova A, Korinek J. Standard blood flow rates of cardiopulmonary bypass are adequate in awake on-pump cardiac surgery. Eur J Cardiothorac Surg 2011;39:442-50.
59. Puja V, Thomas V, Bhat K, Srivastava P, Agarwal S, Sajji R, *et al*. Awake coronary artery bypass grafting in rural cardiac centre in abstracts of the 55th Annual Conference of IACTS, May 2009. Indian J Thorac Cardiovasc Surg 2009;25:147-61.
60. Ram Rao V, Sumit C, Sunil PK, Madhusudana, Maruti H. Awake cardiac surgery under thoracic epidural anaesthesia: Great impact and fast track recovery in 'Abstracts of the 58th Annual Conference of IACTS, February 2012'. Indian J Thorac Cardiovasc Surg 2012;28:33-104.
61. Rieke H, Abernathy JH, Kazmaier S, Mielck F, Hutchenson K, Hanekop G. High thoracic epidural anaesthesia in patients undergoing CABG reduces sympathetic effects on myocardial blood flow and myocardial oxygen uptake and its effect on myocardial ischemia. Anesthesiology and Reanimation 2011;5:150-60.
62. Royse CF, Connelly KA, MacLaren G, Royse AG. Evaluation of echocardiography indices of systolic function: A comparative study using pressure-volume loops in patients undergoing coronary artery bypass surgery. Anaesthesia 2007;62:109-16.
63. Salvi L, Parolari A, Veglia F, Brambillasca C, Gregu S, Sisillo E. High thoracic epidural anesthesia in coronary artery bypass surgery: A propensity-matched study. J Cardiothorac Vasc Anesth 2007;21:810-5.
64. Sendasgupta C, Makhija N, Kiran U, Choudhary SK, Lakshmy R, Das SN. Caudal epidural sufentanil and bupivacaine decreases stress response in paediatric cardiac surgery. Ann Card Anaesth 2009;12:27-33.
65. Sener M, Caliskan E, Bozdogan N, Kocum A, Oner SO, Atalay H, *et al*. Thoracic epidural anesthesia and blood glucose levels in diabetic patients undergoing cardiopulmonary bypass under insulin infusion according to the Portland protocol. Exp Clin Endocrinol Diabetes 2010;118:190-4.
66. Sharma M, Mehta Y, Sawhney R, Vats M, Trehan N. Thoracic epidural analgesia in obese patients with body mass index of more than 30 kg/m^2 for off pump coronary artery bypass surgery. Ann Card Anaesth 2010;13:28-33.
67. Suga K, Yoshida A, Kamada T, Takao R, Kaneko T, Kobayashi Y. Respiratory management for a patient with a giant bulla and pulmonary dysfunction during off-pump coronary artery bypass grafting. Masui 2010;59:216-9.
68. Suryaprakash S, Chakravarthy M, Gautam M, Gandhi A, Jawali V, Patil T, *et al*. Effect of thoracic epidural anesthesia on oxygen delivery and utilization in cardiac surgical patients scheduled to undergo off-pump coronary artery bypass surgery: A prospective study. Ann Card Anaesth 2011;14:192-6.
69. Svircevic V, Nierich AP, Moons KG, Diephuis JC, Ennema JJ, Brandon Bravo Bruinsma GJ, *et al*. Thoracic epidural anesthesia for cardiac surgery: A randomized trial. Anesthesiology 2011;114:262-70.
70. Tenenbein PK, Debrouwere R, Maguire D, Duke PC, Muirhead B, Enns J, *et al*. Thoracic epidural analgesia improves pulmonary function in patients undergoing cardiac surgery. Can J Anaesth 2008;55:344-50.
71. Thammasitboon S, Rosen DA, Lutfi R, Ely BA, Weber MA, Hilvers PN, *et al*. An institutional experience with epidural analgesia in children and young adults undergoing cardiac surgery. Paediatr Anaesth 2010;20:720-6.
72. Torre T, Trunfio R, Mauri R, Siclari F. Multiple valve replacement in limited access: A case report. Heart Surg Forum 2007;10:E408-10.
73. Watanabe G, Ohtake H, Tomita S, Yamaguchi S, Yashiki N, Kato H. Multivessel awake off-pump coronary bypass grafting using median approach: Technical considerations. Innovations (Phila) 2011;6:23-7.
74. Watanabe G, Tomita S, Yamaguchi S, Yashiki N. Awake coronary artery bypass grafting under thoracic epidural anesthesia: Great impact on off-pump coronary revascularization and fast-track recovery. Eur J Cardiothorac Surg 2011;40:788-93.
75. Weiner MM, Rosenblatt MA, Mittnacht AJ. Neuraxial anesthesia and timing of heparin administration in patients undergoing surgery for congenital heart disease using cardiopulmonary bypass. J Cardiothorac Vasc Anesth 2012;26:581-4.
76. UK Medical Protection Society/Advice and publications/Case reports/Vol. 12 no. 3-August 2004/Epidural emergency. Available from: http://www.medicalprotection.org/uk/casebook/august2004/case-reports/epidural-emergency. [Last cited on 2012 Sep 21].

77. Bateman BT, Mhyre JM, Ehrenfeld J, Kheterpal S, Abbey KR, Argalious M, *et al*. The risk and outcomes of epidural hematomas after perioperative and obstetric epidural catheterization: A report from the multicenter perioperative outcomes group research consortium. Anesth Analg 2012 [Epub ahead of print].
78. Volk T, Wolf A, Van Aken H, Bürkle H, Wiebalck A, Steinfeldt T. Incidence of spinal haematoma after epidural puncture: Analysis from the German network for safety in regional anaesthesia. Eur J Anaesthesiol 2012;29:170-6.
79. Heart disease-centers for disease control and prevention. Available from: http://www.cdc.gov/nchs/fastats/heart.htm. [Last cited on 2012 Sep 07].
80. Martinelli SM, Patel UD, Phillips-Bute BG, Milano CA, Archer LE, Stafford-Smith M, *et al*. Trends in cardiac surgery-associated acute renal failure in the United States: A disproportionate increase after heart transplantation. Ren Fail 2009;31:633-40.
81. Lu JC, Grayson AD, Jha P, Srinivasan AK, Fabri BM. Risk factors for sternal wound infection and mid-term survival following coronary artery bypass surgery. Eur J Cardiothorac Surg 2003;23:943-9.
82. Lewis PJ, Dornan T, Taylor D, Tully MP, Wass V, Ashcroft DM. Prevalence, incidence and nature of prescribing errors in hospital inpatients: A systematic review. Drug Saf 2009;32:379-89.
83. US National Cancer Institute, 2009. Available from: http://www.seer.cancer.gov/statfacts/. [Last cited on 2012 Sep 07].
84. Unintentional injury deaths, 2009; Available from: http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2009_ed_web_tables.pdf [Last cited on 2012 Sep 25].
85. Svircevic V, van Dijk D, Nierich AP, Passier MP, Kalkman CJ, van der Heijden GJ, *et al*. Meta-analysis of thoracic epidural anesthesia versus general anesthesia for cardiac surgery. Anesthesiology 2011;114:271-82.
86. Bignami E, Landoni G, Biondi-Zoccai GG, Boroli F, Messina M, Dedola E, *et al*. Epidural analgesia improves outcome in cardiac surgery: A meta-analysis of randomized controlled trials. J Cardiothorac Vasc Anesth 2010;24:586-97.
87. WHO. World report on road traffic injury prevention. Available from: http://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/chapter 2.pdf. [Last cited on 2012 Sep 07].
88. Ho AM, Chung DC, Joynt GM. Neuraxial blockade and hematoma in cardiac surgery: Estimating the risk of a rare adverse event that has not (yet) occurred. Chest 2000;117:551-5.
89. Ruppen W, Derry S, McQuay HJ, Moore RA. Incidence of epidural haematoma and neurological injury in cardiovascular patients with epidural analgesia/anaesthesia: Systematic review and meta-analysis. BMC Anesthesiol 2006;6:10.
90. Ruppen W, Derry S, McQuay H, Moore RA. Incidence of epidural hematoma, infection, and neurologic injury in obstetric patients with epidural analgesia/anesthesia. Anesthesiology 2006;105:394-9.
91. Christie IW, McCabe S. Major complications of epidural analgesia after surgery: Results of a six-year survey. Anaesthesia 2007;62:335-41.
92. Lo CC, Chen JY, Lo YK, Lai PH, Lin YT. Spontaneous spinal epidural hematoma: A case report and review of the literatures. Acta Neurol Taiwan 2012;21:31-4.
93. Arriada-Mendicoa N, Ramos-Peek M. Holospinal epidural haematoma following heart surgery. Rev Neurol 2003;36:530-3.
94. Imanaka K, Kyo S, Yokote Y, Asano H, Tanabe H, Ohuchi H. Paraplegia due to acute spinal epidural hematoma after routine cardiac surgery. Intensive Care Med 2000;26:826.
95. Hayashi I, Shimamura Y, Maehara M. Paraplegia due to spinal epidural hematoma after mitral valve surgery: Report of a case. Surg Today 2011;41:704-6.
96. Hurst PG, Seeger J, Carter P, Marcus FI. Value of magnetic resonance imaging for diagnosis of cervical epidural hematoma associated with anticoagulation after cardiac valve replacement. Am J Cardiol 1989;63:1016-7.
97. Liu SS, Block BM, Wu CL. Effects of perioperative central neuraxial analgesia on outcome after coronary artery bypass surgery: A meta-analysis. Anesthesiology 2004;101:153-61.

Cite this article as: Hemmerling TM, Cyr S, Terrasini N. Epidural catheterization in cardiac surgery: The 2012 risk assessment. Ann Card Anaesth 2013;16:169-77.

Source of Support: Nil, **Conflict of Interest:** None declared.

Invited Commentary

Challenges in measuring and comparing the risk of an iatrogenic epidural hematoma

Meta-analyses integrating the results of multiple independent studies allow consistent interpretation of those studies' results, a more precise estimation of any treatment effect and may explicate variation in the results of individual studies.[1] Hemmerling *et al*.,[2] are performing a major function by using meta-analysis to update prior assessments of the risk epidural catheterization and anesthesia carry in cardiac surgery. However, the validity of meta-analyses depends upon the "combinability" of the individual studies and the completeness and lack of bias in the underlying systematic review from which studies are selected for inclusion in the meta-analysis.[3,4] Further, interpretation of the outcome rates estimated by meta-analysis is strongly influenced by the control group against which those rates are compared, and by the nature of the control group rates with which the meta-analysis generated rates are compared.