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NARRATIVE REVIEW

Iatrogenic trauma following percutaneous and minimally invasive surgical interventions

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Abstract

Technological progress has changed the landscape of surgical practice. Minimally invasive surgery (MIS) and percutaneous interventions (PC) are constantly replacing open procedures. This reduces hospital stay and allows quicker recovery. The application of MIS should follow the good medical practice dictum by Hippocrates i.e. "First do no harm". To remain abreast with new procedures, the medical personnel are required to update and enhance their knowledge and skill. To ensure safety, the innovations are rigorously tested and tried. The learning curve of MIS is shortened by simulator training and proctorship. Credentialing processes are in place to enhance safe delivery of care. Despite of all these measures MIS and PCI are associated with adverse effects. The purpose of this article is to overview the iatrogenic trauma associated with MIS and PCI in major surgical subspecialties.

Keyword: Minimally invasive surgery, Iatrogenic, Trauma, Percutaneous, Endoscopic.

Introduction

Contemporary trend in interventional treatment for surgical disease is towards minimally invasive surgery (MIS) interventions. The introduction of keyhole surgery (laparoscopy), and percutaneous interventions are fast replacing open surgical procedures. The introduction of laparoscopic procedure was a paradigm shift. This heralded the beginning of the MIS era. Laparoscopy itself has undergone multiple innovations and gone less and less invasive. The mini port procedures, single port lap procedures and finally the robot assisted laparoscopic surgeries are some of the examples. Similarly the ability to do wide range of interventions via percutaneous access is another milestone in the modern history of interventional medicine. The MIS on one hand has provided the opportunity of doing surgery with reduced morbidity, early recovery and better cosmetic outcome, on the other hand it is also associated with steep learning curve, and unique set of complications not seen previously with open surgeries. The current review has explored these iatrogenic complications in the era of MIS in various surgical specialties and provided recommendations in the light of contemporary practice guidelines.

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Cardiovascular interventions and iatrogenic trauma

In the current era the standard cardiac surgery has moved towards minimally invasive cardiac surgery (MIS). Similarly advancement in percutaneous techniques have further minimised invasiveness. However, like conventional interventions, they are prone to complications.

Almost all the large peripheral vessels have been used to access the heart. Haemorrhagic complications from invasive cardiac procedures are infrequent. Frequency has been reported to be 3-5% in patients undergoing percutaneous coronary interventions.[1] In MIS there is an additional risk of groin complications including local vascular trauma. In cases of mini thoracotomy and port insertion when used as approach to mitral valve, the breast implants are at particular risk of iatrogenic trauma causing rupture and migration of implant.[2]

During percutaneous coronary intervention perforation of coronary artery may cause cardiac tamponade. Dissection, rupture, wire entrapment and stent placement closing off neighbouring vessel with its drastic consequences needs immediate attention in the form of resuscitation and early surgical intervention.[3,4]

Procedures for structural heart diseases like PC mitral clip for mitral regurgitations, Mitral valve balloon valvuloplasty for severe mitral stenosis and recently popularized Transcutaneous aortic valve implantation (TAVI) for severe aortic stenosis are challenging and complex procedures requiring advanced level of technical expertise. These procedures are associated with inherent risk of valvular damage, failure to deploy valve in proper position, rupture of aorta and left ventricle, aortic

dissection, coronary occlusion, paravalvular leakage leading to acute aortic regurgitation with haemodynamic compromise.[5]

Similarly electrophysiological procedures carry risk of cardiac perforation leading to pericardial effusion and tamponade. These procedures may be pacemaker implantation, radiofrequency ablation for atrial fibrillation, and watchman device to obliterate left atrial appendage. Pericardial tamponade may occur with all kinds of cardiac interventions and warrants urgent action to save lives.[6]

Certain percutaneous interventions are performed to deploy intracardiac devices. Commonly used devices are for congenital cardiac disorders like ASD, VSD PDA and others may be in the form of mitral clip, cinching device for severe MR and watchman device as mentioned earlier. All of these procedures are prone to similar complications. Apart from above, trauma to the aorta including lifting up of intimal flap leading to acute aortic dissection in ascending or descending aorta, aortic rupture perforation with massive haemorrhage may occur.[7,8] The outcome of these iatrogenic traumas depends upon timely recognition, high quality resuscitation and immediate transfer to surgical facility. The surgical management depends upon the nature and extent of injury.[4,9]

ENT interventions and iatrogenic trauma

PC central venous cannulation is a very commonly performed procedure, the most common sites being the internal jugular and subclavian veins. Despite training and experience, this intervention is not risk-free. The complication rate ranges from 0.4% to 9%.[10] These include haematoma, which can potentially expand and obstruct the airway, pneumothorax, haemothorax, pseudoaneurysm, arteriovenous fistula, pulmonary embolism, dissection, stroke and death. Subclavian catheterization is more likely than internal jugular catheterization to be complicated by pneumothorax and haemothorax, whereas internal jugular catheterization is more likely to be associated with arterial puncture. Internal jugular catheterization can be difficult in obese patients due to poorly defined anatomical landmarks. Subclavian venous catheterization should be avoided in patients with severe hypoxaemia, as the complication of pneumothorax is more likely and also poorly tolerated.[11]

There are no definite guidelines to address accidental arterial cannulation. A review from the Canadian Society For Vascular Surgery[12] demonstrated that with a large bore catheter injury, the pull/pressure technique could be associated with significantly higher morbidity than surgical or endovascular management, including stroke, suddenly expanding haematoma causing airway compression, false aneurysm, or death as adequate compression in the cervical area is not possible without jeopardizing cerebral perfusion. According to guidelines if the site of arterial injury is easily surgically accessible open exploration and direct arterial repair should be attempted promptly. Endovascular treatment appears to be safe for the management of arterial injuries that are difficult to expose surgically, such as those below or behind the clavicle. Heparinization should be considered if immediate treatment is not possible. Current guidelines from the American Society of Anesthesiologists Task Force on Central Venous Access recommend that misplaced catheters be left in place and that consultation obtained from a vascular surgeon.[13]

Preventive measures to limit arterial injury include the use of pressure monitoring before placement of the dilator. This technique uses intravenous tubing that is connected to the end of the needle after puncture. The tubing is then elevated and checked for pulsatility and color. If arterial puncture is confirmed, than the needle is removed immediately and pressure is held. Another method to prevent arterial injury is real-time ultrasound guidance. This has reduced the number of central venous access complications but has not eliminated them. Vascular anomalies and anatomic variations of internal jugular vein and surrounding tissues have been observed in up to 36% of patients.[14] Ultrasound identifies the vein size and location, anomalies, and vessel patency, thus avoiding futile attempts in patients with absent or thrombosed veins and congenital anomalies.

Iatrogenic injuries from minimally invasive general surgical interventions: MIS approaches have have revolutionized the surgical management of diseases. Advancements in technology and experience in minimally invasive surgical procedure has made this approach safer. In certain situations it has replaced the open surgery as first line of intervention. Despite widespread acceptance and benefits of MIS, iatrogenic injuries are not uncommon. These complications occur at the time of access to peritoneal cavity, with pneumoperitoneum, during tissue dissection or at the time of closure of ports. According to a survey the distribution of iatrogenic injuries during laparoscopic procedures showed 37% of the injuries were related to bowel and 36% were to major vessel.[15]

Iatrogenic injuries related to camera and instrument ports placement occurs in less than 1% of patients[16] and range from solid and hollow viscus injuries to major vascular trauma. Intra-abdominal adhesions due to prior surgery

or inflammatory conditions like diverticulitis or Crohn's disease, and abdominal distension secondary to large abdominal mass or bowel distension are known risk factors for iatrogenic injury during port placement.[17] With suspicion of abdominal adhesions it is proposed to use visual entry of the first port. However, overall complications related to open access have been reported to be similar to blind entry in experienced hands.[18]

Injuries related to gas insufflation are related to physiological effect of pneumoperitoneum. These include haemodynamic instability from reduced preload to the heart due to compression of inferior vena cava. This is often compounded by vascovagal reflex with pneumoperitoneum.[19] Patients with poor cardiac reserve and hypovolemia are at risk of these complications. Increased intra-abdominal pressure resulting in splitting of diaphragm and absorption of CO2 can severely affect gas exchange especially in obese patients, and with COPD.[20] Other effects related to pneumoperitonium include Deep Venous Thrombosis (DVT) due to pooling of blood in the distal limbs and subcutaneous and mediastinal emphysema. Careful selection of patients and maintaining adequate hydration are crucial to prevent cardiovascular risks of pneumoperitonium. Surgeons' training and experience of performing specific surgical procedure may be related to frequency of iatrogenic injuries but results from various reports are not consistent.[21]

Despite advancements in technology and experience in minimally invasive surgery, iatrogenic injuries are not uncommon. Knowledge of technique and gadgets, structured training and careful handling of instrument is vital to prevent iatrogenic injuries.

Iatrogenic injuries in orthopaedic MIS: There is significant contemporary interest in switching from conventional open technique to minimally invasive technique. This stems from the presumption MIS causes less pain, fewer wound healing problems and earlier functional recovery. However, due to limited exposure during MIS, there may be a risk of injury to structures not directly in vision.[22] This section aims to review various minimally invasive orthopaedic procedures and their associated complication rates.

A literature search was performed in August 2019 on PubMed using the terms, "minimally invasive procedure," "complications," and "orthopaedic procedures". Systematic reviews, Reviews and Meta-analyses were selected if they mentioned complication percentage and risk ratio, or the data available allowed complication rate to be calculated. Altogether 28 articles were included for this review. Publications that were on the same procedure were evaluated for any potential overlap in data sets. In these situations, the article reviewing the largest number of studies that reported on complications was included in the review data set, and the remaining articles were excluded. Data on demographics and reported complication rates was extracted.

The literature review showed that several complications could occur during minimally invasive procedures. In spinal surgery intraoperative complications consisted mostly of abdominal wall paresis, vertebral injuries, neurologic injuries and dural tear[23] while postoperative complications included pneumothorax, lung infection, wound haematoma, or implant loosening.[24] In procedures on extremities, intraoperative complications included nerve palsy and haemorrhage, and postoperative, surgical site infection, insertional tendinopathy, joint stiffness, haematoma formation, wound dehiscence, delayed wound healing, deep vein thrombosis, partial and complete re-ruptures, extreme lengthening of the tendon, chronic fistula, skin necrosis, scar tethering, altered sensation, thrombophlebitis, keloid formation, pain, non-union, delayed union and malunion.[25]

The highest noted complication rate in Humeral, Spine and Foot procedures was 10%, 33%, 14% respectively.[26,27] It was noted that procedures performed in areas with rich vascular or nerve supply were more likely to have a greater complication rate with minimally invasive technique. Thus, such procedures performed in the spinal region showed some of the highest complication rates going up to 33%.[28]

It was also observed that procedures that were performed on a cohort with higher mean age (above 60) had relatively higher complication rates.[29] The development of complications in such cases may be related to age-related factors. However, since several studies included in this article did not report mean age, this relation needs to be investigated further. This variation in complication rates depending on patient characteristics among other factors has been observed in several other studies.[30]

Iatrogenic injuries from Minimally Invasive Neurosurgical Interventions: The last decade has brought significant improvements in the arena of Minimally Invasive Neurosurgical procedures. New technological advancement including Neuronavigation, surgical microscope, fluoroscopy, endoscopy, O-arm, high speed smaller drills and the key hole concept has reduced the short and long term complications as compared to the traditional surgeries with marked improvement in the

effectiveness of these procedures. However, some common and few rare iatrogenic postoperative complications can be broadly divided into two categories.

Iatrogenic Injuries during Minimally Invasive Spine Surgery: The most popular within the armamentarium of minimally invasive spine is percutaneous pedicle screw fixation in thoracic and lumbar spine. Zhao Q, reported an incidence of 5.9% complications during or after surgery. These included intraoperative guide wire breakage, abdominal artery injury, spinal dura mater injury, postoperative pedicle screw misplacement, screw breakage, plug screw falling off, connecting rod loosening, poor reduction, and late infection.[31] A common complication of percutaneous Vertebroplasty and Kyphoplasty is of cement leakage into the spinal canal. The result of a meta-analysis suggested that patients with intravertebral cleft, cortical disruption, low cement viscosity, and high volume of injected cement may be at high risk for cement leakage after Vertebroplasty or Kyphoplasty with incidence of 54.7% and 18.4%, respectively.[32] Another widely performed procedure is Percutaneous Transforaminal or Interlaminar Endoscopic lumbar discectomy. The common cause of failure is the incomplete removal of disc fragments. The skin entry point for the guide-needle trajectory and the optimal placement of the working sleeve are largely blind, which might lead to the inadequate removal of disc fragments. Other reported complications includes nerve root irritation leading to temporary dysesthesia, dural tear and CSF leak, post spinal headache, transient foot drop, intrathecal injection of urograffin dye in the canal, recurrent disc prolapse and infection.[33]

Iatrogenic Injuries during Minimally Invasive Cranial Surgery: Endoscopic endonasal approach has become an integral part of modern skull base surgery. Fallah N[34] reported a large series of giant pituitary adenomas. The complications include new pituitary insufficiency 16.4%, permanent diabetes insipidus 7.5%, and cerebrospinal fluid leakage 5%, meningitis 2.5% and deaths 3.8% occurred in this cohort of patients. In children undergoing similar procedure, aseptic or bacterial meningitis (7.3%) was the most common complication, and the cerebrospinal fluid leakage rate was 2.4%.[35] Carotid artery injury is the most feared and potentially catastrophic intraoperative complication an endoscopic skull base surgeon may face and can be as high as 9% in some surgeries.[36] With Keyhole approaches especially the eyebrow craniotomy, the iatrogenic injury to the supra orbital and frontal branch of facial nerve palsies are as common as 21%.[37]

Conclusion all minimally invasive techniques have a learning curve, therefore a neurosurgeon should be well aware of these complications and iatrogenic injuries. Smaller and simpler lesions should be performed before moving on to larger and more complicated lesions.

Iatrogenic urologic trauma following percutaneous interventions: Percutaneous (PC) interventions on the urinary tract are commonly performed. Iatrogenic injury is a trauma or adverse event incurred as a result of an intervention by a surgeon or interventionist. The rapid rise in the use of MIS and PC although has made possible to avoid complex open, laparoscopic, robot assisted interventions and the related morbidity. However, they are associated with significant and potentially morbid complications as well. Newer energy applications, modifications in surgical techniques, and equipment have all lead to a range and causes of iatrogenic injuries.

One of the commonest elective percutaneous interventions to the upper tract is Percutaneous Nephro Lithotomy (PCNL). Other procedures include percutaneous nephrostomy (PCN) placement for drainage of the kidney, renal biopsy, MIS interventions for ablation of renal tumours, trans perineal and trans rectal biopsies of the prostate etc. PCN is commonly performed for relief of urinary obstruction, urinary diversion, access for endourological procedures, and diagnostics like pressure manometry.[38] Renal biopsies are performed for diagnosis of various medical conditions of the kidney or for suspicious indeterminate masses, small renal masses and prior to initiation of systemic treatment for advanced kidney cancers. Complications in percutaneous renal biopsy are more commonly observed in patients with lower platelet counts had a higher risk of developing severe bleeding events after renal biopsy.[39] The most common complication is bleeding. In a large cohort of patients undergoing renal biopsy Xu and colleagues observed that the incidence of sever bleeding was low (0.4%).[37]

In PCNL, haemorrhage is the most morbid. Vascular injuries are most commonly encountered during access, however it can occur at any time. It is particularly seen if the punctures are too medial or there is a direct access into the renal pelvis. Other injuries include arteriovenous fistula (AVF) or tears in the pelvicaliceal system, causing extravasation and absorption of irrigation fluid.[40] PC renal interventions are associated with many significant complications including haemorrhage, injury to surrounding structures (Bowel, spleen, liver, IVC etc). Haemorrhagic complications are often self-limiting but they can be catastrophic at times with potential of organ loss and even death.

Miniaturization of equipment (mini PCNL, micro PCNL, super mini PCNL, and ultra mini PCNL), improved optics and judicious use of imaging are some of the ways to avoid these complications.

Conclusions

As MIS and PCI have gained popularity the incidence of iatrogenic trauma has increased. The false sense of security with MIS, failure to recognise injury, delay in diagnosis all results in delayed treatment. There is a need for reporting every adverse effect of MIS and PCI. A global reporting site on Internet should be established to accumulate data on procedure responsible for trauma, modalities used for diagnosis and possible treatment and outcome. In conclusion, MIS can have substantial complication rates. There is further need for systematic reviews on a greater variety of MIS with a more comprehensive record of variables and details of complications in order to see the full spectrum of complications from minimally invasive procedures.

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