IBEROAMERICAN JOURNAL OF MEDICINE
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Journal homepage: www.iberoamericanjm.tk

Review

Safety of Laparoscopy in Patients with Ventriculoperitoneal Shunts

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ARTICLE INFO

Article history:
Received 01 February 2021
Received in revised form 20 February 2021
Accepted 05 March 2021

Keywords:
Laparoscopy
Surgery
Ventriculoperitoneal shunts
Safety

ABSTRACT

The relationship between the intra-abdominal pressure (IAP) and intracranial pressure (ICP) has been suspected for more than 100 years and was subsequently confirmed by numerous studies in both animals and humans which demonstrate the link and the positive correlation between IAP and ICP.
There are mounting concerns that the pneumoperitoneum created during laparoscopic surgery to create space for instrument placement and to allow safe tissue dissection may result in an increase in the ICP secondary to the increase in the IAP which may result in serious consequences in patients with Ventriculoperitoneal (VP) shunts.
There is uncertainty about the safety of laparoscopic surgery in VP shunt patients. The aim of this article is to review the literature to answer the question [Is laparoscopic surgery safe in VP shunt patients with and without intraoperative monitoring of ICP]?

HOW TO CITE THIS ARTICLE: Mohamed SA, Mohamed AA. Safety of Laparoscopy in Patients with Ventriculoperitoneal Shunts. Iberoam J Med. 2021;3(2):130-137. doi: 10.5281/zenodo.4589108.

1. INTRODUCTION

Although the first attempt of rerouting cerebrospinal (CSF) from the ventricles to the peritoneal cavity (VP shunt) was performed in 1905, the procedure of VP shunt was abandoned for more than the next 30 years [1]. Surgeons resisted the VP shunt techniques because of frequent occlusion of the tubes and recurrent infections. The introduction of silicone rubber tubes that prevented shunts from occlusion and the development of anti-microbial agents resulted in the revival of the producer [1, 2]. At present, the VP shunt is the standard treatment of hydrocephalus.

Similarly, surgeons resisted and ignored laparoscopy and didn't attempt to test its suitability for surgical applications since 1901, when Georg Kelling performed the first diagnostic laparoscopy on the peritoneal cavity of a dog using a cystoscope [3]. It was until the late eighties of the last century when the advent of computer chip-based television cameras resulted in its revival [4]. At present, laparoscopic surgery became the standard treatment of much surgical pathology.

There is an increased survival of patients with VP shunts

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ISSN: 2695-5075 /
http://doi.org/10.5281/zenodo.4589108

due to the advances in the techniques of cerebral shunts and improved medical therapies. At the same time, there is an increasing trend in laparoscopic surgery. Patients with hydrocephalus are living longer and may present with unrelated medical or surgical problems.

2. HISTORICAL BACKGROUND OF VP SHUNT

Trepanning was recommended by Hippocrates for the treatment of various diseases, including hydrocephalus, and was widely practiced since 400 BC. It was not until around the 17th century those physicians recognized its definitive role of surgical treatment for hydrocephalus [5].

Historically surprisingly, until the beginning of the present century, the pathology of hydrocephalus remained obscure, with no definitive recognized rational methods of therapy or successful surgical treatment [6]. Many practitioners continued to practice primitive methods in attempts to treat hydrocephalus, including repeated percutaneous punctures, head wrapping, and bloodletting, all with consistently fatal results [7].

During the early 20th century, significant progress was made in both understanding the etiology of hydrocephalus and the development of successful surgical treatments for it. This advancement was led by the pioneers of neurosurgery Sir Victor Horsley in England, and Harvey Cushing, Walter Dandy, and others at Johns Hopkins in the US [8].

Walter Dandy was among the first to describe the basic mechanism and classification of hydrocephalus as obstructive or non-obstructive in 1913. He was the first to establish the principles of treatment of hydrocephalus by either reducing cerebrospinal fluids CSF formation, relieving the obstruction, or diverting the fluid to a part of the body in which it can be readily absorbed [9].

The first sterile ventricular puncture and external ventricular drain insertion was performed by Carl Wernicke in 1881 [10]. External drainage by different devices like silk and catgut wicks became quite popular during the late 19th century [11]. However, due to the risks of open drainage, attempts were made at the beginning of the 20th century to introduce mechanisms for internal CSF diversion.

The Polish-Austrian surgeon Jan Mikulicz-Radecki was the first to attempt rerouting of CSF from the ventricles to the subdural space by inserting a mass of glass wool in the shape of a nail into the ventricles of a child in 1893 [12].

The first attempt of rerouting CSF from the ventricles to the peritoneal cavity VP shunt was performed by Kausch, a German neurosurgeon in 1905. The procedure of VP shunt 'fell into disrepute' and was virtually abandoned for more than the next 30 years [1]. Surgeons resisted the VP shunt techniques because of frequent occlusion of the tubes and recurrent infections.

The introduction of silicone rubber tubes that prevented shunts from occlusion and the development of anti-microbial agents resulted in the revival of the producer of VP shunts. [1, 2] Since the introduction of silicone catheters, obstruction by adhesion to proteins and cells of CSF and infections has been a primary focus of ventricular catheters (VC) researches [13].

Many types of VC catheters have been used for VP shunts including silicone (PDMS) catheters, the expanded polytetrafluoroethylene catheters (e-PTFE), VC coated with polyvinylpyrrolidone (PVP). At the turn of the millennium, new advances in VCs were the introduction of catheters (branded Bactiseal), which featured impregnation of 2 antibiotics, Rifampicin and Clindamycin HCL, into the silicone matrix [14].

Today, most VCs are made of silicone polymer tubes and are available in straight configurations that can be tailed to an appropriate length and angled configurations, which have a set length. Inner diameters of the tubing range between 1.0 mm and 1.6 mm and outer diameters between 2.1 mm and 3.2 mm [15].

No doubt the advances in the fields of biomaterials and biomedical engineering made significant contributions to the quality and ability of implanted CSF shunts to allow many patients with VP shunts to live relatively ordinary lives [13].

3. HISTORICAL BACKGROUND OF LAPAROSCOPY SURGERY

The history of laparoscopy dates back to 1901, when Georg Kelling, a German surgeon, performed diagnostic laparoscopy on the peritoneal cavity of a dog using a cystoscope inserted through a trocar with the creation of pneumoperitoneum with filtered air [3]. Around the same time, the Swedish surgeon Dr. Jacobaeous published reports on laparoscopy on humans in the peritoneal, thoracic, and pericardial cavities and was credited with coining the term "laparoscopy" ("laparothorakoskopie") [16].

During the early 20th century, it astonishes the degree to which the surgeons have ignored laparoscopy and didn't attempt to test its suitability for surgical applications. However, gastroenterologists, internists, and gynecologists recognized its inherent value [17].

Since the trials of Georg Kelling and Jacobaeous, no remarkable progress was made until 1929 when Heinz Kalk, a German gastroenterologist, later called Father of Modern Laparoscopy, developed a superior first forward-viewing scope with improved lenses [18].

Heinz's introduction of forward-viewing scope paved the way for the beginning of the era of operative laparoscopy. In 1933 the gynecologist Karl Fervers performed the first laparoscopic operative procedure of lysis of adhesions using cautery [19]. Fevers were followed a few years later by the Swiss gynecologist, Boesch, who performed the first laparoscopic ligation of the Fallopian tubes by electrocoagulation in 1936 [18, 19].

The therapeutic modality of Fervers and Boesch was a definite breakthrough in the field of laparoscopic surgery that laid the foundations for operative laparoscopic surgery; although it took almost one-third of a century since Georg Kelling performed the first diagnostic laparoscopy.

The progress continued to be slow during the next 40 years, and operative laparoscopy was limited only to tubal ligations. By the year 1971, 35 years after Fervers and Boesch's breakthrough, only 1% of tubal ligations were performed laparoscopically in the United States and by 1976, the figure mounted up to reach 60% [19].

The gradual and slow evolution of laparoscopic surgery at its early stages was related to limitations of technology and the skepticism of the medical and surgical communities [20].

It was not surprising that the pioneers of laparoscopic surgery, Kurt Semm, a German gynecologist, who was the first to perform laparoscopic appendectomy in 1983, and the German surgeon Erich Muhe who was also the first to perform laparoscopic cholecystectomy by a 3-cm, direct-vision laparoscope of his own design, in 1986, were both suffered skepticism, criticism and experienced many examples of repression by the old guard of traditional surgery [20, 21].

The most important technological advancement in laparoscopic surgery is the advent of a video laparoscope. Video technology was developing in the 1960s and was being touted for teaching purposes and documentation, as the resolution was not sufficient for operative laparoscopy [22].

The advent of computer chip-based television cameras that project a magnified, view of the filmed object onto monitors and TV screens was considered a revolution in the field of video laparoscopy and laparoscopic surgery.

The French surgeon Phillip Mouret performed the first video laparoscopic cholecystectomy in 1987. He was followed shortly by Francois Dubois, another French surgeon who was the second to perform video laparoscopic cholecystectomy in 1988 and was the first to publish his early experience [23]. The American College of Surgeons introduced the new technology to the general surgery world during the annual meeting of the college in October 1989 [20].

It didn't take long for the laparoscopic cholecystectomy to replace open cholecystectomy. Many papers were published documenting the advantages of laparoscopic surgery over open surgery in terms of less postoperative pain, early postoperative recovery, and early return to work.

Development continued, and still going on, in the field of laparoscopic surgery in terms of improving laparoscopic camera resolutions, the introduction of more refined laparoscopic instruments, and improving surgeon's training to enable surgeons to perform more complex laparoscopic surgical procedures. At present, laparoscopic surgery almost replaced most open surgical procedures.

4. THE RELATION BETWEEN INTRA-ABDOMINAL PRESSURE AND INTRACRANIAL PRESSURE

The intraabdominal pressure (IAP) is a physiological parameter defined as the steady-state pressure concealed within the abdominal cavity [24]. The intravesicular pressure measurement provides a simple, convenient, and accurate measurement of IAP [25]. Values of up to 5mm of Hg are considered normal in adults under normal physiological conditions. [26].

Intracranial pressure is the pressure exerted by fluids such as CSF and blood inside the skull and on the brain tissue. Changes in intracranial pressure (ICP) attributed to changes in the volume of one or more of these constituents. The Monro-Kellie hypothesis states that the cranium is a rigid vault that contains brain tissue, CSF, and blood [27]. If one of the three components increases in size the volume of the other two has to decrease to maintain equilibrium and to prevent a rise of ICP.

The ICP is one of the determinants of the cerebral perfusion pressure (CPP) as the CPP calculated by subtracting the ICP from the mean arterial pressure (MAP): CPP = MAP − ICP [28]. The CPP is normally fairly constant due to autoregulation, but it can be affected to a great extent by sustained changes in the mean arterial pressure and ICP.

The ICP can be measured and monitored by invasive and non-invasive techniques. The invasive techniques include external ventricular drainage through a catheter inserted in the lateral ventricles and micro transducer ICP monitoring devices. The non-invasive techniques include optic nerve sheath diameter, CT scan, MRI, transcranial Doppler, tympanic membrane displacement, and funduscopy [29].

External ventricular drainage is the gold standard in terms of accuracy of measurement of ICP pressure, although micro transducers generally are just as accurate. The non-invasive techniques provide reliable alternatives to the invasive techniques and associated with minor risks of complications such as hemorrhage and infection. ICP is usually measured in millimeters of mercury (mmHg) and, at rest, ranges between 7and 15 mmHg for a supine adult [24].

The relationship between the IAP and the ICP has been suspected for more than 100 years, but it was not clearly identified until Breschet demonstrated the multiple anastomoses and connections between the intracranial venous system and the vertebral venous system in the period between 1828 and 1832 [24].

Batson illustrated in 1957 the extent of connections of the multiple veins of the valveless spinal epidural venous network which was named after him. Batson's work explained the spread of metastasis and infections through these vertebral veins, into the spine and the central nervous system while bypassing both the liver and the lungs [30, 31].

The current evidence strongly supports that the IAP is transmitted to the central nervous system by two pathways. One pathway is retrograde flow through the venous plexus of the spinal canal and the intracranial veins. The second pathway is direct as elevations in the IAP transferred into the thoracic compartment, which in turn results in back pressure on the jugular veins and decreases the drainage of the CSF and blood, leading to an increased ICP [32].

The link and positive correlation between intra-abdominal pressure and intracranial pressure were confirmed by numerous studies in animals [33-36].

Bloomfield G.et al. [33] studied the effects of elevated IAP upon ICP and CPP in an animal model of five anesthetized swine. They increased the IAP to 25 mm Hg above baseline by inflating a balloon inserted inside the peritoneal cavity of the swine, measuring at the same time changes in ICP. They demonstrated a significant and linear increase in ICP with increased IAP and concluded that elevated IAP increases ICP and decreases CPP.

In another animal study, Rosenthal et al. [34] studied the effect of pneumoperitoneum on the ICP in a large animal model of five pigs by recording arterial blood gases, mean arterial blood pressure, and ICP at different measures of IAP both in the supine and Trendelenburg positions. They demonstrated a significant and linear increase in ICP with increased IAP and Trendelenburg positions. The combination of the Trendelenburg position and increased IAP of 16 mmHg results in an increase in the ICP of 150% over control levels. They concluded that surgeons should take into consideration the IAP and Patient positioning when performing laparoscopy on patients with head trauma, cerebral aneurysms, and conditions associated with increased ICP.

A similar study conducted by Halverson et al. [35] by insufflating carbon dioxide at 1.5 l/min in the abdomen of nine 30-35-kg domestic pigs while recording the ICP, lumbar spinal pressure (LP), central venous pressure (CVP), and some others vital parameters. They recorded the different values of ICP at IAP of 0, 5, 10, and 15 mmHg with animals in supine, Trendelenburg, and Reverse Trendelenburg positions. They reported that the animals showed a significant increase in ICP (mmHg) with each 5-mmHg increase in IAP with a further increase occurred with Trendelenburg's position, without a reduction in reverse Trendelenburg positions. The increase in the IAP correlated with the increases in ICP and LP without significant change in CVP. They concluded that care should be taken with laparoscopy in patients at risk for increased ICP. They also suggested that the mechanism of increased ICP associated with insufflations is most likely the impairment of the drainage of the lumbar venous plexus at an increased IAP.

Similarly, Josephs et al. [36] investigated the effect of pneumoperitoneum on ICP and CPP in an animal model of five 30-kg pigs. They monitored ICP, MAP, arterial blood gases, and IAP for 30 minutes before, during, and after the creation of pneumoperitoneum. They demonstrated a positive correlation between IAP and ICP that was independent of changes in arterial PCO2 or arterial PH. They advised that laparoscopy for evaluation of abdominal trauma victims must be used cautiously in patients with severe head injuries.

5. LAPAROSCOPIC SURGERY IN PATIENTS WITH VP SHUNTS

There is an increased survival of patients with VP shunts due to the advances in the techniques of cerebral shunts and improved medical therapies. At the same time, there is an increasing trend in laparoscopic surgery. Patients with hydrocephalus are living longer and may present with unrelated medical or surgical problems [37]. It estimated that the number of patients with CSF shunts in the United States to be greater than 125,000 in 1995 [38]. Many patients with VP shunt may present with an indication for laparoscopic surgery.

There are no absolute contraindications for laparoscopy in patients with VP shunts, although there are always concerns about the risks of an increase in the ICP secondary to an increase in IAP during laparoscopic surgery. The abdomen is usually insufflated during laparoscopic procedures with carbon dioxide to intraabdominal pressure of 12 to15 mmHg to create space for instrument placement and to allow safe tissue dissection during laparoscopic procedures.

The effect of increased intra-abdominal pressures in patients with VP shunts was extensively studied. Raised IAP that occur in individuals with ileus, small-bowel obstruction constipation, has been reported to play a role in malfunctioning VP shunts in patients with hydrocephalus [39].

Many factors have been thought to be the cause of obstruction or malfunction of VP shunts during laparoscopic procedures. Uzzo et al. [40] suggested in addition to the increases in ICP secondary to increases in the IAP, the pneumoperitoneum may increase the resistance to outflow through the distal peritoneal catheter, causing a partial or complete shunt obstruction.

Cobianchi et al. [41] suggested that obstruction of the antegrade flow of the cerebrospinal fluid as a result of increased IAP together with the retrograde passage of carbon dioxide through the shunt catheter result in a sudden increase in ICP during laparoscopic procedures. The hypercapnia-induced cerebral arterial dilatation and venous pressure elevation cause increased intracranial blood volume and increased ICP in the fixed volume of the cranium.

The risk of retrograde passage of carbon dioxide from the abdomen to the brain is minimal with advances in the fields of biomaterials and biomedical engineering and the advent of one-way valve VP shunt catheters that can withstand significantly high IAP pressures before allowing such reflux [42].

The shunt valve's hydrodynamic profile, as derived by catheter manufacturers, is a standard parameter that indicates the pressure that the valve can tolerate before allowing retrograde flow to occur. Most shunts have a one-way valve that can withstand a pressure of 300 mmHg before allowing retrograde flow. Collude et al. [43] suggested that pressure of 12-15 mmHg which is used to insufflate the abdomen during laparoscopic surgical procedures is unlikely to produce pneumocephalus.

The risk of valve failure of shunt valves (*in vitro* model) was studied by Neale et al. [44] in nine different shunt tubes subjected to increased backpressure, and none of them showed signs of valve failure. The risk of valve failure is noticed to be minimal even with IAP as high as 80 mm of Hg [45].

Similarly, Matsumoto et al. [46] studied five different valves simulating a closed system in Japan in 2010. There was no reflux of the CO2 for any of the valves with a pressure of less than 25 mm Hg.8

Surgeons have always been concerned about protecting shunts from potential reflux during laparoscopic surgery on patients with VP shunts. Different methods were advised for temporal protection of the VP shunts during laparoscopic procedures including clamping the shunt catheter intra-abdominally or through a skin incision, and externalizations of the shunt before carbon dioxide insufflation [46]. Some authors advised neurosurgery consultation before surgery to verify the proper function of the VP shunt [37].

The safety of laparoscopic surgery in patients with VP shunts has always been controversial because of the potential risk of an increase in ICP, shunt malfunction, and infection. There is also the question of the need for routine monitoring of ICP intra-operatively [47]. Unfortunately, there is little published data on the issue due to the small number of reported cases and the lack of well-designed studies that include a large number of patients.

Many authors reported the safety of laparoscopic surgery in patients with VP shunt without any precautions apart from routine anesthetic monitoring. On the other hand, some authors reported potential dangerous complications of laparoscopy in patients with VP shunts.

A series of 4 patients with VP shunts who had laparoscopic cholecystectomy without intraoperative ICP monitoring was published by Collure et al. [42]. All patients didn’t show central nervous system sequelae postoperatively and the shunts remained intact and functioning. The authors concluded that laparoscopic cholecystectomy in patients with VP is safe without the need for invasive intraoperative monitoring of ICP or manipulation of the shunt.

A retrospective study conducted by Jackman et al. [48] reviewing the anesthesia records of 18 patients with VP shunt who underwent 19 consecutive laparoscopic operations, looking for signs of increased ICP. They didn't document any evidence of clinically increased ICP and concluded that invasive methods for shunt monitoring are usually not required as routine anesthetic monitoring should remain the standard of care.

In another retrospective study conducted by Fraser et al. [49] reviewing all pediatric patients with VP shunts who underwent laparoscopic and open abdominal operations in their institute in the period from 1998 to 2008. A total of 51 patients were operated laparoscopically out of 99 patients. They reported that there was no air embolism into the shunt in the laparoscopic group. Shunt infection occurred in one patient in the laparoscopic group in comparison to 3 patients in the open group.

Yoshihara et al. [50] were performed laparoscopic cholecystectomy in four patients with shunts (two with ventriculoperitoneal shunts, and two with lumboperitoneal shunts). The shunt catheters were clamped during the pneumoperitoneum in three patients and the intraabdominal pressure was kept at 8 mmHg. They reported that all cases experienced an uneventful postoperative course, with no shunt-associated complications.

A retrospectively from japan reported safe laparoscopic colorectal surgery in four patients with VP shunt who were operated with the pneumoperitoneum pressure set at 10 mmHg under routine anesthetic monitoring and without any manipulations such as clamping or externalization of the VP catheters [51].

One case of VP shunt failure in a patient with shunt-dependent hydrocephalus after laparoscopic placement of feeding jejunostomy was reported by Baskin et al. [52] postoperatively; the patient developed clinical and radiographic evidence of shunt failure and underwent emergent shunt revision that revealed an isolated distal shunt obstruction. They concluded that laparoscopic surgery represents a potential danger in patients with pre-existing CSF shunts.

Schwed et al. [53] reported a case of a 73-year-old woman who had laparoscopic cholecystectomy 10 days after having insertion of a VP shunt. The patient suffered subcutaneous emphysema and impaired respiration immediately after surgery. The patient recovered uneventfully with no evidence of postoperative infection.

6. CONCLUSIONS

VP shunt is the standard treatment of hydrocephalus throughout the world. There has been increasing use of laparoscopic in daily surgical practices as well as an increasing number of patients with VP shunts due to the advances in the techniques of cerebral shunts and improved medical therapies. Surgeons may be faced with patients of VP shunts presenting with an indication for laparoscopic surgery.

Surgeons have always been concerned about the risks of an increase in the intracranial pressures secondary to increases in the IAP during laparoscopic surgery on patients with VP shunts. There is also the question of the need for routine monitoring of ICP intra-operatively.

The safety of laparoscopic surgery in patients with VP shunts has always been controversial. At present, there is no strong evidence to establish a solid consensus on the safety of laparoscopic surgery in patients with VP shunts. However, surgeons are advised to consider certain precautions that may reduce the risk of laparoscopy in this group of patients. As there is only little published data regarding the safety of laparoscopic surgery in patients with VP shunts due to the small number of reported cases and lacks of well-designed studies include a large number of patients, we recommend all cases of laparoscopic surgery in patients with VP shunts be reported to build up base data for futures studies.

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