Scientific Research Publishing

Open Journal of Anesthesiology, 2022, 12, 301-314
https://www.scirp.org/journal/ojanes
ISSN Online: 2164-5558
ISSN Print: 2164-5531

Cardiopulmonary Stability on a Patient with Hip Fracture and Severe Pulmonary Hypertension, Anesthetized with Lumbar-Sacral Plexus Block and Non-Invasive Ventilation: Case Report

Uribe Campo Giselle Andrea[1*], Perales Caldera Eduardo[1], Prol Carreiro Adolfo[1], Velazco González Jose Gamaliel[2], Díaz Borjón Efraín[3], Morales Maldonado Rubén Alejandro[3]

[1]Department of Anesthesiology, Hospital Ángeles Lomas, México City, Mexico
[2]Department of Intensive Care, Hospital Ángeles Lomas, México City, Mexico
[3]Department of Orthopaedics, Hospital Ángeles Lomas, México City, Mexico
Email: *giselle11sa@yahoo.com

How to cite this paper: Andrea, U.C.G., Eduardo, P.C., Adolfo, P.C., Gamaliel, V.G.J., Efraín, D.B. and Alejandro, M.M.R. (2022) Cardiopulmonary Stability on a Patient with Hip Fracture and Severe Pulmonary Hypertension, Anesthetized with Lumbar-Sacral Plexus Block and Non-Invasive Ventilation: Case Report. *Open Journal of Anesthesiology*, **12**, 301-314.
https://doi.org/10.4236/ojanes.2022.1210027

Received: August 30, 2022
Accepted: October 5, 2022
Published: October 8, 2022

Abstract

Background: Pulmonary hypertension is defined as a mean arterial pressure in the pulmonary artery exceeding 20 mm Hg at rest, measured by means of right heart catheterization. Patients with pulmonary hypertension undergoing surgical procedures such as hemiarthroplasty present a high risk of fatal complications. Nonetheless, there are no widely accepted protocols explaining their perioperative care in great detail. **Case presentation:** We present a case with an 89-years-old patient, with comorbidities such as GOLD 4D chronic obstructive pulmonary disease (COPD) and, as a consequence of this, severe pulmonary hypertension with signs of right ventricular dysfunction, thus requiring of pulmonary vasodilator, that has suffered a subcapital hip fracture requiring urgent surgery. Surgery is carried out successfully, under regional lumbar-sacral plexus block and sedation assisted by non-invasive ventilation. **Conclusion:** Multidisciplinary specialized treatment, preoperative optimization, as well as the careful selection of both the surgical and anesthetic techniques to be used, are among the strategies that improve the perioperative outcome in patients with pulmonary hypertension with right ventricle systolic dysfunction. Regional lumbar-sacral plexus block plus sedation is a technique that maintains hemodynamic stability; however, these patients require advance measures and postoperative monitoring under intensive care.

Keywords

Hip Fracture, Pulmonary Hypertension, Lumbar-Sacral Plexus Block, Non-Invasive Ventilation, Right Ventricular Failure

1. Introduction

Pulmonary hypertension is defined as a mean arterial pressure in the pulmonary artery exceeding 20 mmHg at rest, measured by means of right heart catheterization [1]. Nonetheless, hemodynamic definitions that include more data than just the pulmonary pressure during right heart catheterization provide more clinical usefulness, prediction value, as well as a higher impact on the therapy [2]. There are no widely accepted protocols explaining the perioperative care required for patients with pulmonary hypertension [3].

In the United States, from 2004 to 2014, 140,000 patients with pulmonary hypertension underwent 18 million non-cardiac surgeries, and the death/major cardiac events rate found was 4%, the double than the one on patients without pulmonary hypertension ($p < 0.01$) [4].

Perioperative mortality on emergency surgeries is reported as being 15%, while, in orthopedics surgeries, Ramakrishna reported a 30-day mortality of 7% [5]. Other hip replacement surgery studies on these patients report an adjusted mortality risk 4 times higher [6], being a possible explanation for this the high rate of perioperative embolism in bone marrow, with bone debris and cement increasing pulmonary vascular resistance and, thus, triggering the catastrophic acute right ventricular failure [7]. In addition to those risks, these patients present other comorbidities that make them more likely to develop complications such as pneumonia during the postoperative period due to chronic obstructive pulmonary disease (COPD) and obstructive sleep apnea-hypopnea syndrome (OSAHS) [8]; or alterations in their healing capacity due to long-term use of corticosteroids [9].

An appropriate right ventricle coupling to the pulmonary circulation is essential to maintain cardiac output on patients with pulmonary hypertension [10]. Many patients with severe pulmonary hypertension present dilated right ventricle with an increase in filling pressures. This situation usually worsens due to the metabolic response to surgery stress as well as the various pulmonary hypertension crisis perioperative triggers [11].

Due to the significant complication risks in these patients, especially when using general anesthesia, such cases must be approached by a multidisciplinary team, and solutions other than surgery, as well as locoregional anesthetic techniques, must be sought [3].

We present a case with an 89-year-old patient, with comorbidities such as GOLD 4D chronic obstructive pulmonary disease (COPD) and, as a consequence of this, severe pulmonary hypertension with signs of right ventricular dysfunc-

tion, thus requiring of pulmonary vasodilator, that has suffered a subcapital hip fracture requiring urgent surgery. Surgery is carried out successfully, under regional lumbar-sacral plexus block and sedation assisted by non-invasive ventilation. This case report was reviewed and authorized by the Research Ethics Committee in Hospital Angeles Lomas in Mexico (registration number: HAL408/2022).

2. Case Presentation

2.1. Preoperative Assessment

This is an 89-year-old male patient that has suffered a subcapital left hip fracture due to a fall from standing height.

His medical records include Gold 4D chronic obstructive pulmonary disease (COPD) further complicated due to severe pulmonary hypertension and permanent atrial fibrillation.

An echocardiography carried out upon hospital admission reported a pulmonary artery systolic pressure (PASP) of 70 mmHg, a dilated right ventricle with systolic dysfunction by a tricuspid annular plane systolic excursion (TAPSE) of 15 mm and a fractional area change (FAC) of 30% plus moderate tricuspid regurgitation as shown in **Figure 1**.

Left ventricle showed normal contractile function and no regional abnormalities in walls' motion.

The patient displayed a WHO functional class 3, with marked limitation of daily activities but comfortable at rest; and he was receiving Riociguat and diuretics treatment, in addition to a permanent need of supplementary oxygen. Other medicines included were Rivaroxaban and a combination of long-acting inhaled Beta-2 adrenergic agonists and long-acting anticholinergics.

Admission lab studies show a creatinine rise of up to 1.19 mg/dl, with serum electrolyte, blood cell count and clotting time within normal ranges. Among the tests performed, there were markers of myocardial injury, troponin I (Tnl) of 20.6 ng/ml and B natriuretic peptide (BNP) of 326 pg/ml and an electrocardiography that reported an atrial fibrillation with normal ventricular response plus right bundle branch block (**Figure 2**).

The patient enters through hospital emergency room, and there is where the multidisciplinary approach begins, with cardiology, pulmonology (respiratory department), orthopedics, and anesthesiology, for perioperative specialized care and optimization. He is admitted to the Intermediate Care Unit, where the diagnostic approach is completed and the decision is made, by clinical consensus, to perform surgical repair by means of left hip hemiarthroplasty.

Anticoagulation bridging is carried out subcutaneously with Enoxaparin, 40 units every 24 hours, the pulmonary vasodilator is maintained and the fluid intake is adjusted in order to maintain a blood volume with a >1 urinary index.

It is considered an ASA 3 physical status, a high cardiovascular risk according to the Revised Cardiovascular Risk Index (RCRI), a very high thromboembolism

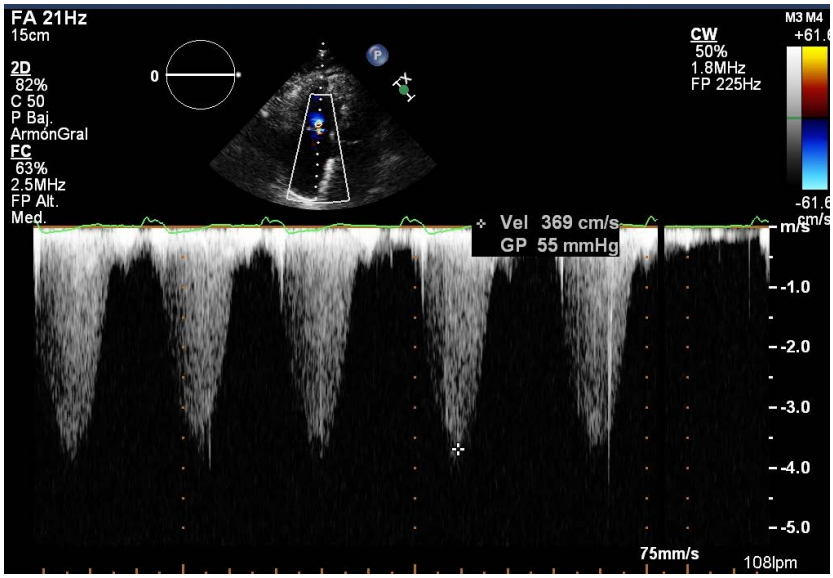

Figure 1. Echocardiogram, pasp.

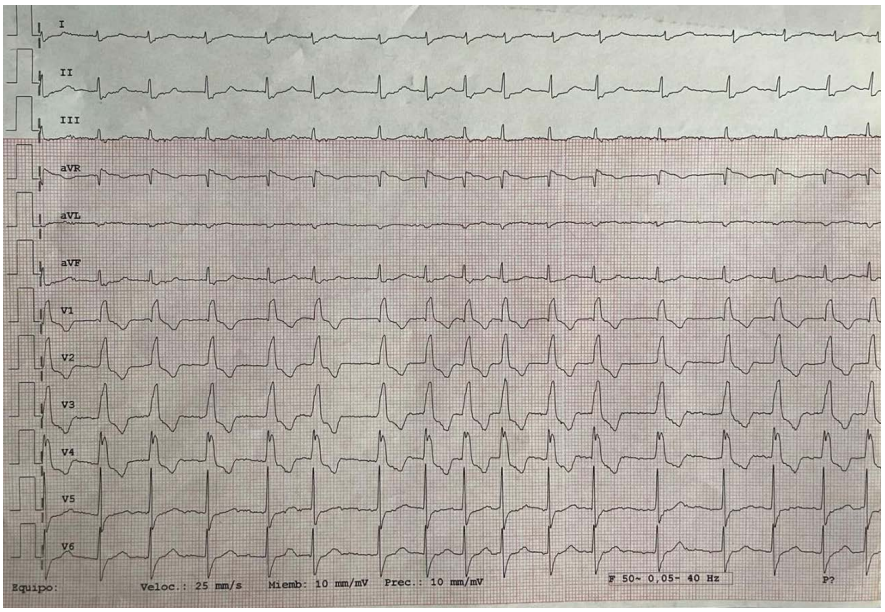

Figure 2. Electrocardiography

risk according to Caprini score, and a high risk (42.1%) of pulmonary complications according to Assess Respiratory Risk in Surgical Patients in Catalonia (ARISCAT). Likewise, the American College of Surgeons (ACS) National Surgical Quality Improvement Program (NSQIP) score predicts a 22% risk of major complications, 20% for mortality, 90% for the need to be permanently monitored upon discharge, 42% for delirium and a predicted hospital stay of 13 days.

2.2. Anesthetic Plan

It is decided to perform regional lumbar-sacral plexus block plus intravenous sedation assisted by non-invasive ventilation. The patient and his relatives are

informed about the general context of the clinical situation, and the respective informed consent is obtained.

2.3. Transanesthetic Monitoring

Vital signs of the patient immediately before the beginning of the anesthetic-surgical procedure were arterial pressure 110/65 mmHg, heart rate of 105 beats per minute, respiratory rate of 16 breaths per minute, oxygen saturation of 95% to a fraction of inspired oxygen of 35%, by nasal catheter.

Standard monitoring plus bispectral index scale (BIS) is established, right radial arterial line and right internal jugular central venous catheter are placed, both guided by ultrasound.

Initial measurement of central venous pressure (CVP) throws a value of 20 cmH_2O and arterial blood gas test is performed, reporting respiratory acidosis with an arterial carbon dioxide tension (PCO_2) of 42.5 mmHg, hemoglobine 10.1 mg/dl, HCO_3 20 mmol/L and lactato 1.3 mmol/L.

Non-invasive ventilation is established with a Phillips B60 ventilator, with the parameters being an inspiratory positive airway pressure (IPAP) of 12 cm H_2O, expiratory positive airway pressure (EPAP) of 8 cmH_2O to a fraction of inspired oxygen (FIO_2) of 60%.

2.4. Induction

Sedation begins with Dexmedetomidine with a loading dose of 0.8 mcg/kg in 10 minutes, thereafter, mean arterial pressure (MAP) drops to 55 mmHg, due to this, administration of norepinephrine begins according to dose-response with a target mean arterial pressure higher than 65 mmHg. No other pharmacological measures are required to achieve that target.

In order to perform the lumbar-sacral plexus block, the patient is placed in the right lateral decubitus position. The lumbar plexus is located following the technique described in 2015 by Karmakar and collaborators [12], with a ultrasound Siemens-branded of the model Acuson p 500, having used the convex transducer 3.5 - 5 mHz. The psoas muscle, the transverse process and the vertebral body of the L4 spinal segment are located; and, under sterile technique, puncture is performed by means of 100 mm Stimuplex needle, until finding a hyperechoic structure adyacent to the vertebral body, compatible with the plexus.

In order to confirm the appropriate nerve location, a PAJUNK nerve stimulator, with voltage of 1 mA and frequency of 1 mHz, was used, thus obtaining psoas and quadriceps contraction, and then, reducing the voltage to a value of 0.4 mA, an adequate distance of the endoneurium is confirmed. Upon verifying absence of blood return, 20 ml of a combination of local anesthesia are administered.

After that, the parasacral sciatic nerve is located, following the technique described by Taha and collaborators in 2011 [13]. With the same ultrasound transducer, the gluteus maximus and piriformis muscles are located at the parasacral level, as well as the greater sciatic notch. Deep in the piriformis muscle, a

hyperechoic structure compatible with the nerve is visualized, appropriate needle location is confirmed with the nerve stimulator, observing dorsiflexion and eversion of the foot, and then 20 ml additional of local anesthesia are administered.

The local anesthesia combination contained 150 mg of ropivacaine at a 0.37% and 400 mg of lidocaine plus epinephrine at a 1%, which are administered at equal portion around both nerves, fractionated in 20 minutes.

2.5. Maintenance

Sedation was maintained with Dexmedetomidine to 0.5 mcg/kg/hr plus Propofol to 20 mcg/kg/mi, obtaining a Bispectral Index Scale (BIS) lower than 60 during the whole surgery.

Surgery began, a bipolar prosthesis is placed, the procedure lasting 60 min, without any incident attributable to the surgery and with a bleeding of 100 ml.

In total, 500 ml of Hartmann solution were administered, monitoring the central venous pressure (CVP) during the surgery to make sure it remained without variations. Diuresis was 100 ml and a positive balance of 165 ml was obtained. Blood transfusion was not deemed necessary.

There were no arterial hypotension events other than the initial one, and no other drugs or additional measures to the norepinephrine administered at the beginning of the sedation were required.

2.6. Emergence

Once finished the surgery, sedation was suspended, thus reducing the need for norepinephrine to maintain a mean arterial pressure (MAP) higher than 65 mmHg, until the vasopressor was finally suppressed.

Non-invasive ventilation was continued with the same parameters, obtaining an arterial blood gas test that reports respiratory acidosis with an arterial carbon dioxide tension (PCO_2) of 41 mmHg, HCO_3 of 20 mmol/L and a central venous blood gas test that reports a venous carbon dioxide tension (PCO_2) of 52 mmHg, a central venous oxygen saturation of 62% and a venous lactate of 1.1 mmol/L. No inotropic support was used during surgery.

The patient was transferred to Intensive Care Unit for postoperative monitoring, with a 0/10 visual analog scale (VAS) for pain and complete motor block on the left lower limb.

2.7. Postoperative Care

The patient is transferred to the ICU under residual effects of sedation, hemodynamically stable without the aid of vasopressor, under mechanic non-invasive ventilation in a 2-level positive airway pressure (BIPAP) mode. No clinical data is received showing tissue hypoperfusion and having the following vital signs: heart rate of 107 beats per minute, mean arterial pressure of 74 mmHg, oxygen saturation of 95%, and a respiratory rate of 17 breaths per minute.

During the first 8 postoperative hours, the patient presented a permanent atrial fibrillation rhythm with paroxysms of rapid ventricular response of up to 140 beats per minute, accompanied by arterial hypotension treated with norepinephrine up to 0.4 mcg/kg/min and controlling the ventricular response by means of Ivabradine, 5 mg per day, to achieve a target heart rate of 115 beats per minute.

Additionally, a progressive decrease was appreciated in the central venous oxygen saturation, as described in Table 1, with an increase in the need of O_2 in order to maintain normoxemia. A pulmonary hypertension crisis is suspected due to data showing a hypodynamic cardiogenic shock, thus beginning milrinone administration to 0.15 mcg/kg/min.

Inotropic support and vasopressor suspension are achieved in the first 24 postoperative hours.

The patient is decoupled from the non-invasive ventilation in his third postoperative day and he is transferred to the intermediate care unit; once there, tight monitoring continues, as well as analgesic administration with paracetamol, at prescribed hours, and tramadol, when needed.

He is discharged and sent home in his seventh postoperative day, with supplemental oxygen via nasal cannula and usual oral pulmonary vasodilator.

2.8. Follow Up

On the postoperative outpatient appointment, a survival of 60 postoperative days is documented, without any major cardiac events, without readmission to the hospital and without complications like pneumonia or venous thromboembolism.

The patient requires a caregiver during the day, walking with the support of a cane and receives rehabilitation therapy for the left pelvic limb at home. He has not required increased medications for the management of pulmonary hypertension or other heart conditions.

3. Discussion

Patients with pulmonary hypertension undergoing surgical procedures with

Table 1. Blood gas tests (first postoperative hours).

POP HRS	SAMPLE	Ph	PCO_2	HCO_3	CENTRAL VENOUS O_2 SAT	LACTATE
2 hr	ARTERIAL	7.29	43 mmHg	20 mmol/L		
2 hr	VENOUS	7.28	47 mmHg		41%	1.7
6 hr	ARTERIAL	7.27	44.5 mmHg	19.6 mmol/L		
6 hr	VENOUS	7.24	47.2 mmHg		47.2%	1
10 hr	ARTERIAL	7.29	43.7 mmHg	20.2 mmol/L		
10 hr	VENOUS	7.26	46.6 mmHg		53.5%	1

general anesthesia present a high risk of fatal complications [4] [14] [15] [16]. Events that usually occur during the perioperative stage, such as the sympathetic nervous system activation, hypoxemia, hypercapnia, use of positive end-expiratory pressure (PEEP) and mechanical ventilation have disastrous effects on pulmonary hemodynamics, and they can trigger right ventricular failure and cardiac arrest [17]. Other events, such as pain and high fluid exchange rate, also have a negative effect in the right ventricular function [3]. Even when care for these patients is provided in highly specialized centers, perioperative mortality remains high [3].

In this case, we decided to use regional lumbar-sacral plexus block, as an alternative to neuraxial anesthesia and general anesthesia, since it covers the dermatomes, myotomes and osteotomes of lower limb's anterior, lateral, medial and posterior regions and it has been attributed by reports a 93.7% success rate [18] [19] [20], thus allowing for the surgery to be carried out comfortably for the patient and the surgeon, provided it is mandatorily accompanied by sedation.

The election of the most appropriate anesthetic technique depends on the patient's clinical situation and surgery's requirements such as position, duration, surgical site and risk of cardiovascular instability due to fluid exchange [21].

There are very few similar case reports in the literature, Korai *et al.* in 2019, described a case of a patient with syringomyelia and severe pulmonary hypertension, who suffered a hip fracture. The surgery management was considered prohibitive. However, the patient underwent surgery under lumbar-sacral plexus block and sedation and assisted ventilation with Cpap. The outcome was successful, postoperative intensive care was not required and the patient was discharged after 3 days. The case report does not describe the patient's hemodynamic status intraoperative, nor survival during follow-up. Even so, the data presented suggest that the lumbar-sacral block technique is safe and efficient in this type de patient [22].

Homeometric autoregulation is an adaptation mechanism that allows for the right ventricle to maintain the systolic function when faced with a high pulmonary vascular resistance, this occurs when the systolic volume is maintained, regardless of the Frank-Starling Law [11]. However, certain factors can alter this autoregulation, for example, the sympathetic block in neuraxial anesthesia, which produces rapid vasodilation; vasovagal stimulation and anesthetic medicines, most of which have a negative inotropic effect and deleterious effects in pulmonary vascular resistance [23]-[29]. These factors are frequent when administering general and neuraxial antesthesia but, on patients with pulmonary hypertension and right ventricular dysfunction, they can trigger cardiogenic shock and sudden death.

The benefits reported with peripheral nerves anesthesia-analgesia are: cardiovascular stability with an adequate pain control and low use of opioids with absence of adverse effects inherent to other analgesic techniques [21].

An adequate postoperative analgesia is a challenge in this type of patients with comorbidities such as chronic obstructive pulmonary disease (COPD) accompa-

nied by chronic carbon dioxide (CO_2) retention and on whom opioids are not an option due to the increased risk of pulmonary complications. Or, like in this case, a patient that presents chronic renal insufficiency, for whom the non-steroidal anti-inflammatory drugs are not desirable. Regional peripheral nerves block offers an advantage in that, with just one local anesthetic dose, a residual analgesia of up to 48 hours is achieved, with a significant reduction in the need for opioids and other analgesics [30].

Nonetheless, the advantages of the anesthesia chosen in this case can be overshadowed if the need for sedation comes accompanied with effects such as hypercapnia and vasodilation. For that reason, we decided to complement the technique, in an early and preventive manner, with the support of non-invasive ventilation, which has shown benefits on patients with conditions such as chronic obstructive pulmonary disease (COPD) [31].

Right ventricular perfusion depends more on mean arterial pressure (MAP) than on diastolic arterial pressure, since the right coronary artery flow supplies the right ventricle during the whole cardiac cycle, due to the low intraventricular pressure [32]. Hence, preventing right coronary ischemia is key [3]. Therefore, it is very important to place an invasive arterial line before beginning with the anesthesia. In this case, posterior artery hypotension occurred at the beginning of the sedation, corrected by administering norepinephrine labeled with a target mean arterial pressure exceeding 65 mmHg, monitored by means of invasive arterial line.

On patients with pulmonary hypertension and preserved left ventricle function, the right ventricle is independent and subject to changes in the preload. Due to this, central venous pressure (CVP) monitoring can be useful to assess changes in the right ventricle filling pressures, and its global function, during procedures in which high fluid exchange or bleeding is expected [33]. Normally, the right ventricle can dilate and adapt to high volumes, however, a chronic rise in pulmonary pressure can produce hypertrophic changes, reducing its capacity to adapt to different volumes and, hence, on pulmonary hypertension crises during which pulmonary arterial pressure suddenly rises, the right ventricle distends and fails. As a consequence, there is a left deviation in the interventricular septum, with a decrease in the cardiac output of both ventricles and cardiogenic shock [34], for this reason, monitoring is recommended for central venous oxygen saturation, venoarterial carbon dioxide (CO_2) gradient and lactate.

Monitoring with pulmonary catheter or perioperative echocardiography requires general anesthesia and depends on the operator and the availability of equipment [3].

Regarding the surgical procedure, hip hemiarthroplasty is an appropriate procedure on patients with a very high cardiovascular risk, such as in this case, in order to prevent complications related to the mobility deprivation and pain caused by a hip fracture, but also to minimize the impact of the metabolic response to the trauma produced by the anestethic-surgical procedure on right ventricular function and hemodynamics, as previously described [35].

Most of the events related with right ventricular dysfunction occur within the next 48 to 72 hours after procedures that did not seem to present any immediate complications, therefore, postoperative monitoring in the Intensive Care Unit is desirable [3]. Pulmonary hypertension crises with decrease in cardiac output, arterial hypotension and congestive cardiac failure, are associated with a mortality of over 50% [36].

Urban *et al.* in 2014 presented a case report of a patient with mixed connective tissue disease, vasculitis and severe pulmonary hypertension, who suffered avascular necrosis of the femoral head and was scheduled for total hip arthroplasty. The surgery is performed under neuraxial anesthesia and sedation, a vasopressor infusion was used and intraoperative events were not reported. The patient was not monitored in intensive care unit and in the first 12 postoperative hours, she presents arterial hypotension, metabolic acidosis and renal insufficiency, which is suspicious for a pulmonary hypertensive crisis. The patient is treated with intravenous fluids and requires intubation and mechanical ventilation. Her status hemodynamic worsens with sustained tissular hypoperfusion and increased pulmonary vascular resistance, measured by pulmonary artery catheter. She did not respond to pulmonary vasodilators and died on her 5th postoperative day [37].

The immediate recognition of a pulmonary hypertension crisis is essential, with a wide range of triggering factors that goes from anesthetic induction, laryngoscopy, mechanic ventilation up until perioperative inflammation, pulmonary microembolisms, hypothermia, arrhythmia, and high fluid exchange [3].

The approach to these crises focuses on:

1) Aggressively addressing the hypotension in order to prevent right ventricular ischemia without reducing the pulmonary vasodilators [3].

2) Treating the specific triggering factor (hypothermia, sedation effects) and optimizing oxygen supply [21].

3) Reducing pulmonary vascular resistance with the use of intravenous or inhaled pulmonary vasodilators, such as nitric oxide, iloprost, milrinone and sildenafil [38].

4) Improving right ventricle function: this is achieved optimizing contractility and preload with appropriate target central venous pressure (CVP) values for each patient and reducing the afterload with the pulmonary vasodilators. Strategies aiming this include diuresis monitoring and the use of inotropics such as dobutamine and milrinone [39].

4. Conclusions

Multidisciplinary specialized treatment, preoperative optimization, as well as the careful selection of both the surgical and anesthetic techniques to be used, are among the strategies that improve the perioperative outcome in patients with pulmonary hypertension with right ventricle systolic dysfunction, despite the fact that their risk assessment predicts many potentially fatal complications.

Regional lumbar-sacral plexus block plus sedation is a technique that maintains hemodynamic stability in these patients, due to its low deleterious effects in pulmonary vascular resistance and in right ventricular function and perfusion. However, these patients require advanced, specific measures such as early recognition and treatment of pulmonary hypertension crises and postoperative monitoring in the Intensive Care Unit, in order to preserve such stability.

Limitations

Regional peripheral nerves blocks are anesthetic techniques that require of a special technical training. They are not widely known and require of experience, both for its application and in having the ability to solve adverse events derived from any potential failure.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Simonneau, G., Montani, D., Celermajer, D.S., *et al.* (2019) Haemodynamic Definitions and Updated Clinical Classification of Pulmonary Hypertension. *European Respiratory Journal*, **53**, Article ID: 1801913. https://doi.org/10.1183/13993003.01913-2018

[2] Yaghi, S., Novikov, A. and Trandafirescu, T. (2020) Clinical Update on Pulmonary Hypertension. *Journal of Investigative Medicine*, 1-7. https://doi.org/10.1136/jim-2020-001291

[3] Price, L., Martinez, G., Brame, A., *et al.* (2021) Perioperative Management of Patients with Pulmonary Hypertension Undergoing Non-Cardiothoracic, Non-Obstetric Surgery: A Systematic Review and Expert Consensus Statement. *British Journal of Anaesthesia*, **126**, 774-790.

[4] Smilowitz, N.R., Armanious, A., Bangalore, S., Ramakrishna, H. and Berger, J.S. (2019) Cardiovascular Outcomes of Patients with Pulmonary Hypertension Undergoing Noncardiac Surgery. *American Journal of Cardiology*, **123**, 1532-1537. https://doi.org/10.1016/j.amjcard.2019.02.006

[5] Kaw, R., Pasupuleti, V., Deshpande, A., *et al.* (2011) Pulmonary Hypertension: An Important Predictor of Outcomes in Patients Undergoing Non-Cardiac Surgery. *Respiratory Medicine*, **105**, 619-624. https://doi.org/10.1016/j.rmed.2010.12.006

[6] Kiely, D.G., Condliffe, R., Webster, V., *et al.* (2010) Improved Survival in Pregnancy and Pulmonary Hypertension Using a Multiprofessional Approach. *BJOG*, **117**, 565-574. https://doi.org/10.1111/j.1471-0528.2009.02492.x

[7] Koessler, M.J., Fabiani, R., Hamer, H. and Pitto, R.P. (2001) The Clinical Relevance of Embolic Events Detected by Transesophageal Echocardiography during Cemented Total Hip Arthroplasty: A Randomized Clinical Trial. *Anesthesia & Analgesia*, **92**, 49-55. https://doi.org/10.1097/00000539-200101000-00010

[8] Gupta, R.M., Parvizi, J., Hanssen, A.D. and Gay, P.C. (2001) Postoperative Complications in Patients with Obstructive Sleep Apnea Syndrome Undergoing Hip or Knee Replacement: A Case-Control Study. *Mayo Clinic Proceedings*, **76**, 897-905.

https://doi.org/10.1016/S0025-6196(11)62108-3

[9] Arozullah, A.M., Khuri, S.F., Henderson, W.G. and Daley, J. (2001) Development and Validation of a Multifactorial Risk Index for Predicting Postoperative Pneumonia after Major Non-Cardiac Surgery. *Annals of Internal Medicine*, **135**, 847-857. https://doi.org/10.7326/0003-4819-135-10-200111200-00005

[10] Vonk Noordegraaf, A., Chin, K.M., Haddad, F., *et al.* (2019) Pathophysiology of the Right Ventricle and of the Pulmonary Circulation in Pulmonary Hypertension: An Update. *European Respiratory Journal*, **53**, Article ID: 1801900. https://doi.org/10.1183/13993003.01900-2018

[11] Wink, J., De Wilde, R.B.P., Wouters, P.F., *et al.* (2016) Thoracic Epidural Anesthesia Reduces Right Ventricular Systolic Function with Maintained Ventricular-Pulmonary Coupling. *Circulation*, **134**, 1163-1175. https://doi.org/10.1161/CIRCULATIONAHA.116.022415

[12] Karmakar, M.K., Li, J.W., Kwok, W.H. and Hadzic, A. (2015) Ultrasound-Guided Lumbar Plexus Block Using a Transverse Scan through the Lumbar Intertransverse Space: A Prospective CASE Series. *Regional Anesthesia & Pain Medicine*, **40**, 75-81. https://doi.org/10.1097/AAP.0000000000000168

[13] Taha, A.M. (2012) A Simple and Successful Sonographic Technique to Identify the Sciatic Nerve in the Parasacral Area. *Canadian Journal of Anesthesia*, **59**, 263-267. https://doi.org/10.1007/s12630-011-9630-3

[14] Deljou, A., Sabov, M., Kane, G.C., *et al.* (2020) Outcomes after Noncardiac Surgery for Patients with Pulmonary Hypertension: A Historical Cohort Study. *Journal of Cardiothoracic and Vascular Anesthesia*, **34**, 1506-1513. https://doi.org/10.1053/j.jvca.2019.10.059

[15] Ramakrishna, G., Sprung, J., Ravi, B.S., Chandrasekaran, K. and McGoon, M.D. (2005) Impact of Pulmonary Hypertension on the Outcomes of Noncardiac Surgery: Predictors of Perioperative Morbidity and Mortality. *JACC*: *Journal of the American College of Cardiology*, **45**, 1691-1699. https://doi.org/10.1016/j.accreview.2005.08.229

[16] Kaw, R., Pasupuleti, V., Deshpande, A., Hamieh, T., Walker, E. and Minai, O.A. (2011) Pulmonary Hypertension: An Important Predictor of Outcomes in Patients Undergoing Non-Cardiac Surgery. *Respiratory Medicine*, **105**, 619-624. https://doi.org/10.1016/j.rmed.2010.12.006

[17] Meyer, S., McLaughlin, V.V., Seyfarth, H.J., *et al.* (2013) Outcomes of Noncardiac, Nonobstetric Surgery in Patients with PAH: An International Prospective Survey. *European Respiratory Journal*, **41**, 1302-1307. https://doi.org/10.1183/09031936.00089212

[18] Gatner, E., Fouché, E., Choquet, O., *et al.* (2022) Bloqueo del nervio periférico ciático: Puntos de referencia y técnica de estimulación nerviosa. https://www.nysora.com/es/t%C3%A9cnicas/extremidad-baja/bloqueo-del-nervio-ci%C3%A1tico/

[19] Ortigosa, E. (2022) Técnicas de bloqueo por vía posterior. Bloqueo de plexo lumbar por vía posterior. https://arydol.com/temas/ultrasonograf%C3%ADa/miembro-inferior/bloque-plexo-lumbar/tecnicas-de-bloqueo-por-via-posterior/

[20] Perales, E., González, A., Uribe, G., *et al.* (2021) Lumbar-Sacral Plexus Block Anesthesia versus General Anesthesia for Total Hip Arthroplasty: Case Control Study. *Open Journal of Anesthesiology*, **11**, 259-268. https://doi.org/10.4236/ojanes.2021.119025

[21] Wood, C. (2021) Perioperative Management of Patients with Pulmonary Hypertension and Right Ventricular Dysfunction. https://resources.wfsahq.org/anaesthesia-tutorial-of-the-week/atow-459-00

[22] Koraki, E., Gkiouliava, A., Zosimidis, D., *et al.* (2019) Regional Anesthesia as an Individualized Approach for a Patient with Syringomyelia and Severe Pulmonary Hypertension Undergoing Surgery for Hip Fracture. A Case Report. *The Greek E-Journal of Perioperative Medicine*, **18**, 31-36.

[23] Kinsella, S.M. and Tuckey, J.P. (2001) Perioperative Bradycardia and Asystole: Relationship to Vasovagal Syncope and the Bezold-Jarisch Reflex. *British Journal of Anaesthesia*, **86**, 859-868. https://doi.org/10.1093/bja/86.6.859

[24] Saouti, N., Westerhof, N., Postmus, P.E. and Vonk-Noordegraaf, A. (2010) The Arterial Load in Pulmonary Hypertension. *European Respiratory Review*, **19**, 197-203. https://doi.org/10.1183/09059180.00002210

[25] Warnaar, N., Molenaar, I.Q., Colquhoun, S.D., *et al.* (2008) Intra-Operative Pulmonary Embolism and Intracardiac Thrombosis Complicating Liver Transplantation: A Systematic Review. *Journal of Thrombosis and Haemostasis*, **6**, 297-302. https://doi.org/10.1111/j.1538-7836.2008.02831.x

[26] Lu, K., Xu, M., Li, W., Wang, K. and Wang, D. (2017) A Study on Dynamic Monitoring, Components, and Risk Factors of Embolism during Total Knee Arthroplasty. *Medicine* (*Baltimore*), **96**, e9303. https://doi.org/10.1097/MD.0000000000009303

[27] Pearce, B., Hu, R., Desmond, F., Banyasz, D., Jones, R. and Tan, C.O. (2019) Intraoperative TOE Guided Management of Newly Diagnosed Severe Tricuspid Regurgitation and Pulmonary Hypertension during Orthotopic Liver Transplantation: A case Report Demonstrating the Importance of Reversibility as a Favorable Prognostic Factor. *BMC Anesthesiology*, **19**, Article No. 128. https://doi.org/10.1186/s12871-019-0795-6

[28] Naeije, R. and Badagliacca, R. (2017) The Overloaded Right Heart and Ventricular Interdependence. *Cardiovascular Research*, **113**, 1474-1485. https://doi.org/10.1093/cvr/cvx160

[29] Sarkar, M.S. and Desai, P.M. (2018) Pulmonary Hypertension and Cardiac Anaesthesia: Anesthesiologist's Perspective. *Annals of Cardiac Anaesthesia*, **21**, 116-122.

[30] Chan, E.Y., Fransen, M., Parker, D.A., Assam, P.N. and Chua, N. (2014) Femoral Nerve Blocks for Acute Postoperative Pain after Knee Replacement Surgery. *Cochrane Database of Systematic Reviews*, **5**, Cd009941. https://doi.org/10.1002/14651858.CD009941.pub2

[31] Cabrini, L., Nobile, V.P., Plumari, G., *et al.* (2014) Intraoperative Prophylactic and Therapeutic Non-Invasive Ventilation: A Systematic Review. *British Journal of Anaesthesia*, **112**, 638-647. https://doi.org/10.1093/bja/aet465

[32] Crystal, G.J. and Pagel, P.S. (2018) Right Ventricular Perfusion: Physiology and Clinical Implications. *Anesthesiology*, **128**, 202-218. https://doi.org/10.1097/ALN.0000000000001891

[33] Elif Sade, L., Gulmez, O., Eroglu, S., Sezgin, A. and Muderrisoglu, H. (2007) Noninvasive Estimation of Right Ventricular Filling Pressure by Ratio of Early Tricuspid Inflow to Annular Diastolic Velocity in Patients with and without Recent Cardiac Surgery. *Journal of the American Society of Echocardiography*, **20**, 982-988. https://doi.org/10.1016/j.echo.2007.01.012

[34] Wood, C., Balciunas, M., Lordan, J. and Mellor, A. (2021) Perioperative Management of Pulmonary Hypertension. A Review. *The Journal of Critical Care Medicine*, **7**, 83-96. https://doi.org/10.2478/jccm-2021-0007

[35] Liu, Y., Chen, X., Zhang, P. and Jihang, B. (2020) Comparing Total Hip Arthroplasty and Hemiarthroplasty for the Treatment of Displaced Femoral Neck Fracture in the Active Elderly over 75 Years Old: A Systematic Review and Meta-Analysis of Randomized Control Trials. *Journal of Orthopedic Surgery and Research*, **15**, Article No. 215. https://doi.org/10.1186/s13018-020-01725-3

[36] Simon, M. (2013) Perioperative Management of Pulmonary Hypertensive Crisis. *Advances in Pulmonary Hypertension*, **12**, 38-39. http://meridian.allenpress.com/aph/article-pdf/12/1/38/1352787/1933-088x-12_1_38.pdf https://doi.org/10.21693/1933-088X-12.1.38

[37] Urban, M.K. and Jules-Elysee, K.M. (2014) A Patient with Severe Pulmonary Hypertension for Hip Arthroplasty. *HSSJ*, **10**, 171-179. https://doi.org/10.1007/s11420-014-9383-y

[38] Hoeper, M., Galie, N., Murali, S., *et al.* (2002) Outcome after Cardiopulmonary Resuscitation in Patients with Pulmonary Arterial Hypertension. *American Journal of Respiratory and Critical Care Medicine*, **165**, 341-344. https://doi.org/10.1164/ajrccm.165.3.200109-0130c

[39] Monagle, J., Manikappa, S., Ingram, B. and Malkoutzis, V. (2015) Pulmonary Hypertension and Pregnancy: The Experience of a Tertiary Institution over 15 Years. *Annals of Cardiac Anaesthesia*, **18**, 153-160. https://doi.org/10.4103/0971-9784.154466