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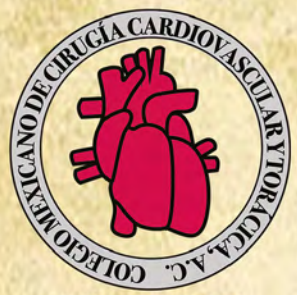

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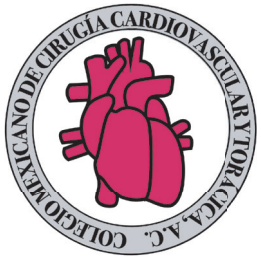

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EDITORIAL
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Valve-sparing aortic root replacement. Which technique is better? A challenge that we must take

Reemplazo de la raíz aórtica con preservación de la válvula. ¿Cuál técnica es mejor? Un desafío que debemos asumir

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Keywords: aortic root aneurysm, David procedure, Yacoub procedure, aortic valve repair.

Palabras clave: *aneurismas de raíz de aorta, procedimiento de David, procedimiento de Yacoub, reparación de la válvula aórtica.*

Life is like riding a bicycle: to maintain balance, you must keep moving.
Albert Einstein

Since the 1960s the procedure introduced by Dr. Bentall and Dr. DeBono has been the gold standard surgery for aortic root aneurysms; but, after the introduction of valve-sparing operations in the 1990s, they have generated increasing interest for the treatment of root aneurysm with pliable bicuspid or tricuspid aortic cusps; however, medical evidence for repairing the aortic valve rather than replacing it remains low.[1]

The two main techniques are the Yacoub procedure (remodeling) and the David procedure (reimplantation). The possibility to preserve the aortic valve (AV), restore its function and replace the dilated part of ascending aorta has become a game-changing concept in approach to aortic root and/or regurgitant AV.[2] The most important point is that the patient will be free of the risks inherent in the presence of an aortic prosthesis.

Aortic valve-sparing procedures should mimic the physiological behavior of the aortic root to restore proper valve coaptation through (1) resuspension of the cusp effective height, (2) reduction of the dilated root diameters (aortic annular base and sinotubular junction), and (3) preservation of root dynamics with vortices (sinuses of Valsalva) and expansibility (interleaflet triangles).[3-5]

Both procedures are of the same age and have been reproduced by many centers, this has generated various results and there has been a constant debate over which of the two above mentioned techniques is superior; the remodeling technique provides physiologic cusp movement within the three reconstructed neo-sinuses, thus preserving root expansibility through the interleaflet triangles, but it does not address annular base dilation.[6,7]

On the other hand, the reimplantation procedure as an inclusion technique performs a subvalvular annuloplasty through the proximal suture of the graft but withdraws the sinuses of Valsalva and includes the interleaflet triangles

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within the noncompliant prosthesis, thus impairing root dynamics.[7]

Exists studies that compare the hydrodynamics of remodelling versus reimplantation on porcine roots in vitro with significantly smoother valve movement in remodelling configuration, which could eventually lead to slower valve degeneration.[8] This is one of the observed phenomena that have shown that remodeling is more physiological, remembering that it not only gives a normal displacement of the cusps, but it also allows the natural movement of the annulus during cardiac contraction.

Last year has been performed a similar comparison including remodelling, reimplantation and reimplantation into Valsalva graft, they found that this graft provided the most similar characteristics to the native root in terms of energy loss and valve opening.[9]

Recently a meta-analysis of fifteen studies met eligibility criteria, comprising 3044 patients (1991 in the reimplantation group and 2018 in the remodeling group). They found that patients who underwent valve-sparing aortic root surgery with remodeling had a higher risk of all-cause death Landmark analysis (with 4 years as the landmark time point) demonstrated that survival was lower in patients who underwent remodeling in the first 4 years. Beyond the 4-year time point, no difference in survival was observed. The risk for need of aortic valve and/or root reintervention was higher in patients undergoing remodeling.

They did not find statistically significant coefficients for the covariates of age, female sex, connective tissue disorders, bicuspid aortic valve, aortic dissection, coronary bypass surgery, total arch replacement, or annular stabilization, which means that these covariates did not modulate the effects observed in their pooled analyses. They concluded that the reimplantation is associated with better overall survival and lower risk of need for reintervention over time compared with remodeling. Regarding overall survival, they observed a time-varying effect that favored the reimplantation technique up to 4 years of follow-up, but not beyond this time point.[10]

Despite this meta-analysis comprising observational studies, the 15 studies yielded many patients that allows a good comparison of both techniques and the results obtained have statistical weight. However, the comparison of the techniques was carried out in patients who underwent remodeling without modification of the aortic annulus reinforcement. In 2006, Lansac et al. published the use of an expandable ring placed in the external part of the aortic root, this was after they observed that in young patients, after remodeling, the dilation of the ring was not controllable and is the cause of late aortic insufficiency.[11]

In 2016, Schäfers et al. suggested an external PTFE suture surrounding the ring;[12] This is more reproducible, less need for deep dissection of the aortic root and less risk of late injuries due to the presence of material in that region, in addition if there is a relevant height discrepancy between the basal plane and the aorto-ventricular junction, external dissection sufficient to place an external annuloplasty device will be difficult.

There are many studies and modifications to the remodeling technique, good long-term results have been achieved. Lansac introduced the term: CAVIAAR technique (Conservative Aortic Valve surgery for Aortic Insufficiency and Aneurysm of the Aortic Root), a standardized and physiologic-driven approach to aortic valve repair. By combining key elements of established remodeling techniques. CAVIAAR effectively addresses both aortic root aneurysm and valve insufficiency, through: (1) a physiologic reconstruction of the aortic root according to the remodeling technique; (2) resuspension of the cusp effective height; and (3) external placement of an expansible subvalvular aortic ring annuloplasty.[13]

After 5 years, they published the early experience with CAVIAAR technique versus mechanical Bentall in 261 consecutive patients with aortic root aneurysm who were enrolled in multicentric prospective cohort (131 in the BENTALL group, 130 in the REPAIR group) in 20 centers. The main end point was composite criterion including mortality; reoperation; thromboembolic, hemorrhagic, or infectious events; and heart failure. Secondary endpoints were major adverse valve-related events. The mean age was 56.1 years, and the valve was bicuspid in 115 patients (44.7%). The median preoperative aortic insufficiency grade was 2.0 (1.0-3.0) in the REPAIR group and 3.0 (2.0-3.0) in the BENTALL group. Thirty-day mortality was 3.8% (n = 5) in both groups (p = 1.00). Despite a learning curve and longer cross clamp times for valve repair (147.7 vs 99.8 minutes, $p < 0.0001$), the 2 groups did not differ significantly for the main criterion or 30-day mortality, with a trend toward more frequent major adverse valve-related events in the BENTALL group. At discharge, 121 patients (96.8%) in the REPAIR group had grade 0 or 1 aortic insufficiency. With their results, they concluded that a new standardized approach to valve repair, combining an expansible aortic annuloplasty ring with the remodeling technique, presented similar 30-day results to mechanical BENTALL with a trend toward reducing major adverse valve-related events.[14]

This year has been published a retrospective international multicentre study of patients undergoing remodelling or reimplantation.[15] The aim was to compare AV reimplantation (David procedure) and aortic root remodelling including basal ring annuloplasty (Yacoub procedure) regarding the longer-term freedom from AV perioperative outcomes were analyzed along with longer-term freedom from AV reoperation/reintervention and other major valve-related events.

One hundred and twelve pairs were selected and further compared. In the remodeling, they did not find a statistically significant difference in perioperative outcomes between the matched groups. Patients after remodelling had significantly higher reintervention risk than after reimplantation over the median follow-up of 6 years ($p = 0.016$). The remodelling technique, need for decalcification and degree of immediate postoperative AV regurgitation ($p < 0.001$) were defined as independent risk factors for later AV reintervention. After exclusion of patients with worse than mild AV regurgitation immediately after repair, both techniques functioned comparably ($p = 0.089$) AV reimplantation was associated with better valve function in longer-term postoperatively than remodelling. But, if optimal immediate repair outcome was achieved, both techniques provided comparable AV function. The debate will continue because many centers continue to develop valve-sparing surgery; some more remodeled, others reimplanted. The interesting thing should be that smaller centers start an aortic root surgery program where we can have a complete treatment arsenal and individualize the patient. The techniques exist but each patient is different and therefore, the correct path is which patient is for each technique.

In 2021, David et al.[16] published their last report of reimplantation; a total of 465 patients who had reimplantation of aortic valve from 1989 to 2018 were followed prospectively with periodic clinical and echocardiographic assessments. Mean follow-up was 10 ± 6 years and 98% complete. At 20 years, 69.1% of patients were alive and free from aortic valve reoperation, and the cumulative probability of aortic valve reoperation with death as a competing risk was 6.0%, and the cumulative probability of developing moderate or severe AI was 10.2%. Only time per 1-year interval was associated with the development of postoperative. As we can see, over 30 years the percentage of reintervention for valve insufficiency has been very low. Initial reports mentioned up to 11% over 10 years.

In Mexico, the first report of valve-sparing aortic root replacement was in 2018 by García-Villarreal et al.[17] They present a case of aortic root aneurysm successfully repaired with the David V technique. Three years later we published a series of 14 cases of patients with aneurysm of the aortic root and/or ascending aorta with some degree of aortic valve insufficiency, successfully undergoing valve reimplantation with the David I technique, the initial results have been successful, and after 10 years we do not have reintervention.[18]

While it is true, there are many surgeons in Mexico who perform aortic root surgery, but, this only two reports of cases in our country, reflects that we do not have well-established aortic root surgery programs.

As is already known, both aortic valve preservation procedures have the main advantage of avoiding the risks inherent to valve prostheses (endocarditis, thrombosis, bleeding); that is why cardiac surgeons must have the ability to develop and indicate them according to each patient. Remodeling is more physiological than reimplantation, however, reimplantation has greater durability, therefore, in young patients and/or patients with collagenopathy, it seems to be the best option.[2]

There may be fear of failure and the need for early reinterventions and/or prolonged surgical times in non-successful cases that are converted to Bentall. The learning curve may be long, but we must start and gain the necessary experience. Let's get our minds and hands going.

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ORIGINAL ARTICLE

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Hepatotoxic effects of lactated Ringer's solution in patients undergoing cardiac surgery at a national referral center

Efectos hepatotóxicos del lactato de Ringer en pacientes sometidos a cirugía cardiaca en un centro de referencia nacional

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ABSTRACT

Objective: we describe a case series of twelve patients who underwent cardiac surgery that developed acute hepatic failure (AHF) following the administration of Lactated Ringer's solution (LRS). **Material and methods:** an observational and retrospective study was carried out. Patients diagnosed with AHF undergoing cardiac surgery from January 1, 2018 and December 31, 2018, were included; perioperative characteristics and conditions were considered. **Results:** these patients received a mean of 100 ml/h of LRS for a hypovolemic replacement over about 3.8 ± 2.7 days. AHF and hepatocellular damage pattern, was confirmed in twelve patients and is potentially associated with drug-induced liver injury (DILI) due to LRS. At follow-up, four patients were discharged from the hospital, while eight died during hospital stay. **Conclusions:** carefully assessing lactic acid levels and liver enzymes in cardiac surgery patients during their intensive care unit stay before starting infusion with LRS is important. The prevention of hyperlactatemia complications requires an initial assessment of lactate metabolism.

Keywords: hepatotoxic activity, lactated Ringer's solution, acute hepatic failure, cardiac surgery.

RESUMEN

Objetivo: *describimos una serie de casos de doce pacientes sometidos a cirugía cardiaca que desarrollaron insuficiencia hepática aguda (IHA) tras la administración de lactato de Ringer (LR).* ***Material y métodos:*** *se realizó un estudio observacional y retrospectivo. Se incluyeron pacientes diagnosticados de IHA sometidos a cirugía cardiaca entre el 01 de enero de 2018 y el 31 de diciembre de 2018; se consideraron las características y condiciones perioperatorias.* ***Resultados:*** *estos pacientes recibieron un promedio de 100 ml/h de LR para un reemplazo durante aproximadamente 3.8 ± 2.7 días. En doce pacientes se confirmó IHA y un patrón de daño hepatocelular, potencialmente asociado a la lesión hepática inducida por fármacos (LHIF) debido a LR. Durante el seguimiento, cuatro pacientes recibieron el alta hospitalaria, mientras que ocho fallecieron durante su estancia en el hospital.* ***Conclusiones:*** *la evaluación cuidadosa de los niveles de ácido láctico y enzimas hepáticas en pacientes de cirugía cardíaca durante su estancia en la unidad de cuidados intensivos antes de iniciar la infusión con LR es importante. La prevención de complicaciones por hiperlactatemia requiere una evaluación inicial del metabolismo del lactato.*

Palabras clave: *hepatotoxicidad, solución de lactato de Ringer, insuficiencia hepática aguda, cirugía cardiaca.*

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Abbreviatures:
AHF = acute hepatic failure
AKI = acute kidney injury
ALP = alkaline phosphatase
ALT = alanine aminotransferase
AST = aspartate aminotransferase
AVR = aortic valve replacement
DILI = drug-induced liver injury
ICU = intensive care unit
LDH = lactate dehydrogenase
LRS = lactated Ringer's solution
MVR = mitral valve replacement
pCO_2 = partial pressure of carbon dioxide
RUCAM = Roussel Uclaf causality assessment method
ULN = upper limit of normal

Patients who have undergone cardiac surgery, large volumes of crystalloid solutions, such as lactated Ringer's solution (LRS), are commonly administered to mitigate the effects of decreased tissue perfusion. The recommended dose of LRS ranged from 500 to 3,000 ml every 24 hours. Administration rates are adjusted based on the patient's clinical status, usually not exceeding 5 ml/kg/h.[1] However, using LRS could exacerbate basal serum lactate levels in some patients, leading to micro vascular and macrovascular circulation changes, a systemic inflammatory response, and subsequent organ damage. Particularly, hyperlactatemia could result in diffuse liver damage, characterized by a rapid and marked elevation of serum aminotransferases.[2] The prolonged exposure to hyperlactatemia may cause cellular and systemic dysfunction, resulting in severe metabolic acidosis, and in some cases, death. Although a relative increase in serum lactate levels is a common finding after cardiac surgery, the administration of LRS might drive the onset of severe hyperlactatemia and eventually, acute liver failure as a rare complication during the postoperative period.[3,4]

In this study, we describe a series of twelve cases who underwent cardiac surgery and further developed acute hepatic failure (AHF) during their intensive care unit (ICU) stay after receiving LRS as the initial replacement fluid therapy.

MATERIAL AND METHODS

We conducted a case series study of twelve patients undergoing cardiac surgery at the Instituto Nacional de Cardiología Ignacio Chávez from January 01, 2018 and December 31, 2018. We collected information on demographics, comorbidities, diagnoses, invasive procedures, biochemical parameters of liver function, and acid-base parameters of arterial gases (hydrogen potential (pH), partial pressure of carbon dioxide (pCO_2), bicarbonate (HCO_3^-), and serum lactate) during the first seven days of ICU stay. We determined whether there was an acid-base disturbance (metabolic acidosis, respiratory alkalosis, or mixed alkalosis).[5] AHF was defined according to the following: elevation of alanine aminotransferase (ALT) > 5 times the upper limit of normal (ULN) or alkaline phosphatase (ALP) > 2 times the ULN. Pattern of liver damage was defined as hepatocellular if the ULN of ALT or aspartate aminotransferase (AST) was greater than 5, cholestatic if there was a predominant elevation of ALP, and mixed if there was a combination of both.[6] We used the Roussel Uclaf causality assessment method (RUCAM) to determine the presence of drug-induced liver injury (DILI). Clinical outcomes included mortality or hospital discharge; additionally, we analyzed the relationship between acid-base disturbance, altered lactate metabolism, LRS administration, and acute liver injury. The IRB approved the study (INCAR-DG-DI-DI-CI-053-2023), adhering to the Declaration of Helsinki and following the CARE guidelines.

Data was collected using the REDCap electronic software (Vanderbilt University, Nashville, Tenn).[7] Continuous variables were presented as mean (± standard deviation) or median (interquartile range) according to the Anderson-Darling normality test. Categorical variables were presented as frequency and absolute proportion. Plots to visualize the changes in biochemical parameters and follow-up status were built with the ggplot2 R package.[8] We conducted all statistical analyses using R Studio version 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Sociodemographic and clinical profile

Table 1 displays the sociodemographic and clinical characteristics at admission. The age ranged between 19 and 76, with a mean of 44.9 ± 16.8 years. Women made up 58% (n = 7) of the sample. The most common comorbidities were systemic arterial hypertension (33.3%, n = 5), type 2 diabetes mellitus (16.6%, n = 2), and chronic kidney disease (16.6%, n = 2). The admission diagnoses included one patient with acute aortic dissection type Stanford A and two with mitral regurgitation. Other diagnoses are shown in *Table 2*.

Cardiac surgery evaluation

Aortic valve replacement (AVR) and mitral valve replacement (MVR) were performed in six patients (50%), while Bentall-De Bono procedure was conducted in two patients (16.6%) *(Table 1)*. The twelve underwent cardiac surgery using cardiopulmonary bypass (CPB). The mean CPB time was 194 ± 68 minutes, aortic cross-clamping was 129 ± 35 minutes, temperature was 28 ± 4 °C, and the operative bleeding was 718 ± 386 ml.

Clinical condition

Table 2 shows patients' clinical findings during hospitalization. After the cardiac surgery, all patients were transferred to the ICU with normal hepatic function parameters. All patients received a mean dose of 100 ml per hour of LRS for hypovolemic replacement with a mean duration of 3.8 ± 2.7 days. During the first seven days of ICU stay, we observed clinical manifestations of increased lactate levels, lactic dehydrogenase, and clinical and laboratory evidence of hepatic damage (increase in the ALT/AST ratio) *(Figure 1)*. Postoperative metabolic acidosis was observed in seven patients (58.3%) and metabolic acidosis/mixed in five (41.6%) patients, which confirmed the clinical pattern of lactate metabolism deterioration. We observed confirmed acute hepatic failure in twelve patients (91.6%) due to marked elevation of ALT/AST greater than 5 ULN.

Table 1: Overall patient characteristics (N = 12).

Characteristics	Total n (%)
Female	7 (58)
Age (years)	44.9 ± 16.8
Body mass index (kg/m^2)	24.6 ± 3.6
NYHA class	
I	2 (16.6)
II	5 (41.6)
III	4 (33.3)
IV	1 (8.5)
Comorbidities	
Systemic arterial hypertension	5 (33.3)
Type 2 diabetes mellitus	2 (16.6)
Chronic kidney disease	2 (16.6)
Dyslipidemia	1 (8.3)
Smoking	3 (25)
Alcoholism	2 (16.6)
Cardiac surgery type	
Aortic valve replacement	3 (25)
Mitral valve replacement	3 (25)
Bentall-De Bono procedure	2 (16.6)
Others	4 (33.3)
Surgery characteristics	
CPB (min)	194 ± 68
Aortic cross-clamp (min)	129 ± 35
CPB Temperature (°C)	28 ± 4
Operative bleeding (ml)	718 ± 386
Biochemical evaluation	
pH (−log[H+])	7.3 ± 3.3
pCO2 (mmHg)	32 ± 5.4
HCO3− (mmol/l)	22.4 ± 4.0
Serum lactate (mmol/l)	1.3 ± 0.25
LDH (U/l)	151.5 ± 60.2
AST (U/l)	25.6 ± 10.7
ALT (U/l)	41.7 ± 43.7
Outcomes	
Length of hospital stay (days), median (IQR)	9 (IQR: 2.5-22.3)
Mortality	8 (66.7)

ALT = alanine aminotransferase. AST = aspartate aminotransferase. CPB = cardiopulmonary bypass. IQR = interquartile range. LDH = lactate dehydrogenase. NYHA = New York Heart Association.

Early outcomes

The median length of hospital stay was 9 (IQR:2.5-22.5) days. Four patients were discharged by clinical improvement, while eight died during hospitalization. The main causes of death were AHF (25%, n = 2), cardiogenic shock (37.5%, n = 3), septic shock (25%, n = 2), and mixed shock (12.5%, n = 1) *(Table 2 and Figure 1)*.

DISCUSSION

This case series evidenced that among 12 patients who were treated with LRS, 12 developed AHF and subsequently 8 died. Acute liver failure is feared complication in the ICU; DILI is diagnosed through the exclusion of other potential liver conditions and confirmed by relating potentially hepatotoxic substances to alterations in the liver's biochemical profile.[9] The increase in liver enzymes and temporal relationship with drug intake are the hallmark indicators of DILI, as there is currently no secure and accurate method for diagnosing it.[10] The most common type of DILI is hepatocellular, accounting for 52-75% of cases and characterized by a significant rise in ALT and/or AST concentrations due to drug administration.[10]

Exposure of hepatocytes to stress, most likely involving reactive metabolites, mitochondrial dysfunction, and oxidative stress, is believed to trigger DILI.[11] Inhibition of cytoplasmic (glycolysis) or mitochondrial (Krebs's cycle, oxidative phosphorylation) pathways leads to inadequate ATP production despite adequate amounts of oxygen and glucose, resulting in pyruvate and lactate accumulation under aerobic conditions, a situation known as cytotoxic hypoxia.[12] Histologic risk reduction and hypoxia impact the enzymatic pathways of pyruvate and lactate metabolism by stimulating anaerobic glycolysis and altering mitochondrial function, reducing lactate utilization and clearance. When the mitochondrial oxidative chain fails to generate NAD^+, pyruvate is reduced to lactate to produce NAD^+ and hypoxia affects both lactate utilization pathways.[13] In this context, LRS contains 28 mEq of lactate per liter and is the only solution that undergoes normal cellular metabolism in the liver, responsible for 60% of lactate clearance. During its metabolism as part of the Cori cycle, lactate is transformed into pyruvate and then into HCO_3^-.[2] A decrease

Table 2: Acid-base alterations and liver function before and after of cardiac surgery.

Patient	Initial diagnosis	Cardiac surgery	Drugs during the surgery	Laboratories		Acid-Base Disorder	Postoperative liver injury (ALT/AST > 5 LSN)	Ringer's lactate solution dose (ml/h/day)	Clinical outcome
				Preoperative	Postoperative				
1	Infective endocarditis (aortic valve)	AVR (mechanical)	Vasopressin Norepinephrine Levosimendan Dobutamine Midazolam Fentanyl Fast insulin	Lactate ↕ pH ↕ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↕ LDH ↑	Lactate ↑ pH ↓ pCO_2 ↓ HCO_3^- ↓ ALT ↑* 4 AST ↑ LDH ↑	Metabolic and/or mixed acidosis	Hepatocellular (ALT ↑)	100 ml/h/1 day 60 ml/h/1 day 40 ml/h/2 days 10 ml/h/2 days	Improvement
2	Mixed aortic valve disease	AVR and MVR (mechanical)	Vasopressin Norepinephrine Levosimendan Dobutamine Fentanyl Midazolam FAST insulin Dexmedetomidine	Lactate ↕ pH ↕ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↓	Lactate ↑ pH ↓ pCO_2 ↓ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic and/or mixed acidosis	Hepatocellular (ALT ↑)	100 ml/h/4 days 5 ml/h/1 day	Acute liver failure
3	Mitral regurgitation	MVR (biological)	Norepinephrine Dobutamine Levosimendan Furosemide Fentanyl Midazolam	Lactate ↕ pH ↕ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↕ pCO_2 ↕ HCO_3^- ↓ High NA AST ↑ LDH ↑	Metabolic and/or mixed acidosis	Hepatocellular (ALT ↑)	60 ml/h/2 days	Cardiogenic shock
4	Tetralogy of Fallot	Correction with bovine pericardial patch	Norepinephrine Fentanyl Vasopressin Midazolam Amiodarone	Lactate ↕ pH ↓ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↓ HCO_3^- ↓ High NA AST ↑ LDH ↑	Metabolic and/or mixed acidosis	Hepatocellular (ALT ↑)	100 ml/h/1 day	Cardiogenic shock

Continues Table 2: Acid-base alterations and liver function before and after of cardiac surgery.

Patient	Initial diagnosis	Cardiac surgery	Drugs during the surgery	Laboratories		Acid-Base Disorder	Postoperative liver injury (ALT/AST > 5 LSN)	Ringer's lactate solution dose (ml/h/day)	Clinical outcome
				Preoperative	Postoperative				
5	Mitral stenosis	MVR (mechanical)	Vasopressin Norepinephrine Levosimendan Fentanyl Midazolam Milrinone	Lactate ↕ pH ↓ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↓ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (ALT ↑)	100 ml/h/1 day 50 ml/h/2 days	Acute liver failure
6	Acute aortic dissection (Stanford A)	Replacement of supracoronary aorta and aortic arch	Vasopressin Levosimendan Norepinephrine Dobutamine Fentanyl Midazolam	Lactate ↕ pH ↕ pCO_2 ↓ HCO_3^- ↓ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↑ HCO_3^- ↓ High NA AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (ALT ↑)	100 ml/h/1 day	Cardiogenic shock
7	Acute aortic dissection (Stanford A)	Bentall-De Bono procedure	Vasopressin Norepinephrine Levosimendan Morphine Dobutamine Fentanyl Midazolam	Lactate ↕ pH ↕ pCO_2 ↓ HCO_3^- ↕ ALT ↑ AST ↕ LDH × 1.1	Lactate ↑ pH ↓ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (AST ↑)	60 ml/h/1 day 100 ml/h/1 day	Septic shock (AKI and AHF)
8	Mixed aortic valve disease and mitral regurgitation	AVR and MVR (biological)	Vasopressin Norepinephrine Levosimendan Dobutamine Fentanyl Midazolam	Lactate ↕ pH ↕ pCO_2 ↕ HCO_3^- ↕ ALT ↓ AST ↕ LDH ↕	Lactate ↑ pH ↕ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (AST ↑)	100 ml/h/1 day 50 ml/h/2 days	Septic shock (AKI and AHF)

Continues Table 2: Acid-base alterations and liver function before and after of cardiac surgery.

Patient	Initial diagnosis	Cardiac surgery	Drugs during the surgery	Laboratories		Acid-Base Disorder	Postoperative liver injury (ALT/AST > 5 LSN)	Ringer's lactate solution dose (ml/h/day)	Clinical outcome
				Preoperative	Postoperative				
9	Aortic prosthetic dysfunction	AVR (mechanical)	Vasopressin Norepinephrine Dobutamine Fentanyl Milrinone Morphine	Lactate ↕ pH ↕ pCO_2 ↓ HCO_3^- ↓ High NA AST ↕ LDH ↑	Lactate ↑ pH ↓ pCO_2 ↑ HCO_3^- ↓ High NA AST ↑ LDH ↑	Metabolic and/or mixed acidosis	None	100 ml/h/1 day 30 ml/h/1 day 10 ml/h/5 days	Improvement
10	Myocardial infarction	Coronary artery bypass grafting	Vasopressin Norepinephrine Dobutamine Fentanyl Midazolam	Lactate ↕ pH ↕ pCO_2 ↓ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (ALT ↑)	300 ml/h/1 day 60 ml/h/1 day 10 ml/h/1 day 0 ml/h/4 days 80 ml/h/1 day 40 ml/h/1 day	Septic shock and multi-organ failure
11	Acute aortic dissection (Stanford B)	Bentall-De Bono procedure	Vasopressin Norepinephrine Levosimendan Fentanyl Midazolam FAST insulin	Lactate ↑ pH ↕ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (AST ↑)	100 ml/h/1 day 200 ml/h/2 days 20 ml/h/7 days	Improvement
12	Chronic pulmonary thromboembolism	Bilateral pulmonary thromboendarterectomy	Vasopressin Norepinephrine Levosimendan Dopamine Dexmedetomidine Dobutamine Fentanyl	Lactate ↕ pH ↕ pCO_2 ↕ HCO_3^- ↕ ALT ↕ AST ↕ LDH ↕	Lactate ↑ pH ↓ pCO_2 ↕ HCO_3^- ↓ ALT ↑ AST ↑ LDH ↑	Metabolic acidosis	Hepatocellular (AST ↑)	100 ml/h/1 day 40 ml/h/1 day	Improvement

↑ = Increased by 1 normal upper limit. ↓ = decreased by 1 normal upper limit. ↕ = normal values. AHF = acute hepatic failure. AKI = acute kidney injury. ALT = alanine aminotransferase. AST = aspartate aminotransferase. AVR = aortic valve replacement. LDH = lactate dehydrogenase. MVR = mitral valve replacement. pCO_2 = partial pressure of carbon dioxide.

Contents

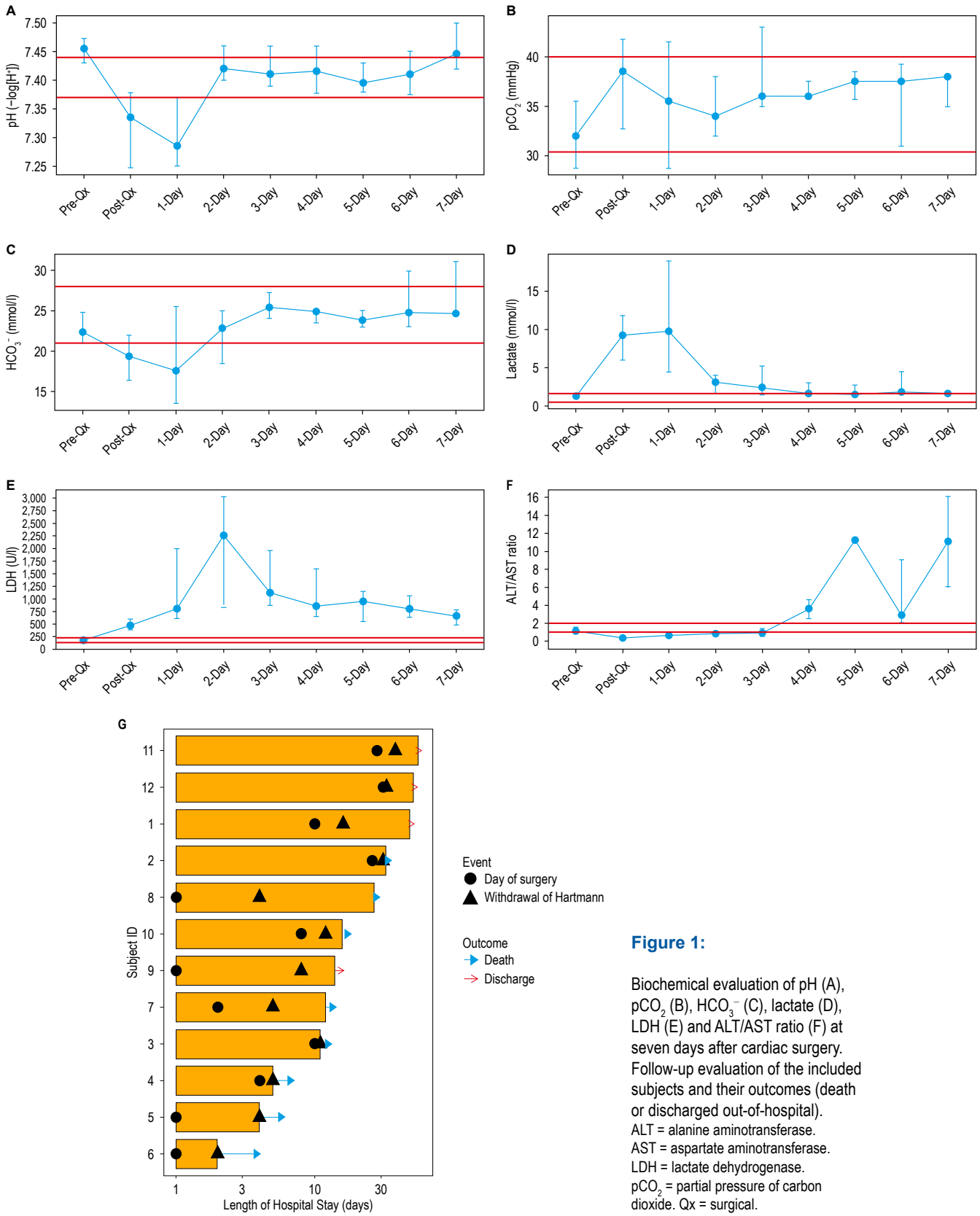

Figure 1:

Biochemical evaluation of pH (A), pCO_2 (B), HCO_3^- (C), lactate (D), LDH (E) and ALT/AST ratio (F) at seven days after cardiac surgery. Follow-up evaluation of the included subjects and their outcomes (death or discharged out-of-hospital).
ALT = alanine aminotransferase.
AST = aspartate aminotransferase.
LDH = lactate dehydrogenase.
pCO_2 = partial pressure of carbon dioxide. Qx = surgical.

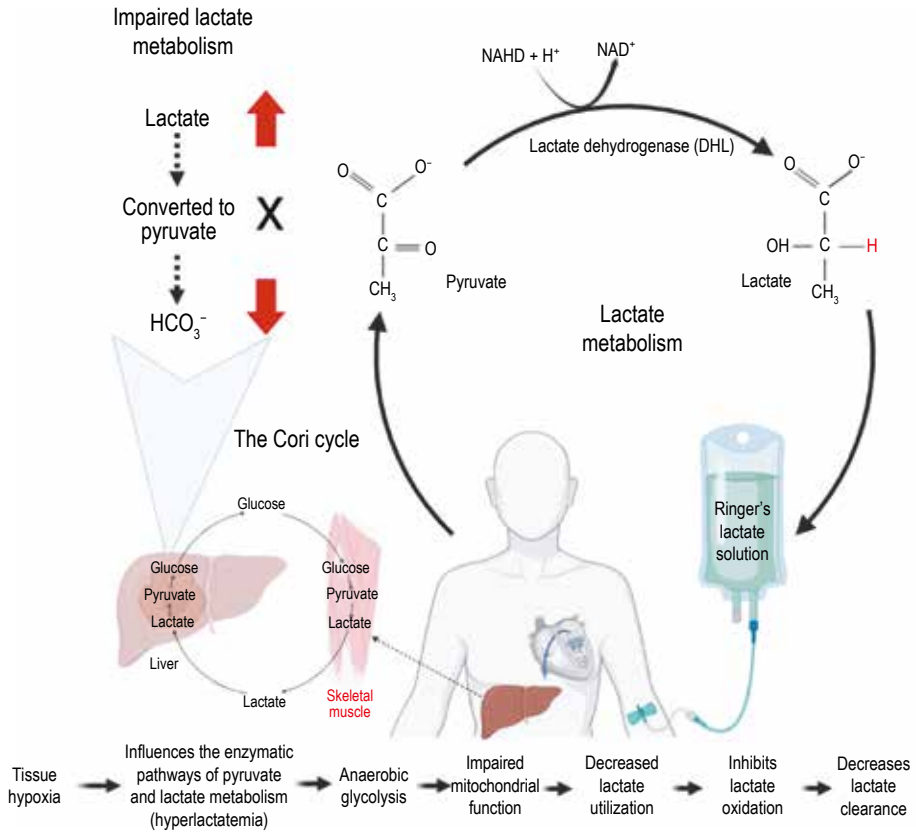

Figure 2:

Pathophysiological evaluation of lactate metabolism involved in acute hepatic failure.

in HCO_3^- and an increase in lactate indicate an alteration in lactate metabolism and excessive lactate administration beyond clearance can result in negative multiorgan effects. There is a theoretical possibility that administering large amounts of LRS could worsen existing lactic acidosis in septic shock and other states of peripheral hypoperfusion, which is further increased if there are bacterial infections and septic shock.[14,15] The potential relationship between serum lactate concentration and the dose of LRS administered with liver function alteration is shown in *Figure 2*, but further clinical studies are needed to confirm this relationship in septic shock and other states of peripheral hypoperfusion. Zitek et al., conducted a randomized clinical trial that examined the relationship between LRS administration and an increase in serum lactate levels, comparing healthy volunteers receiving LRS to those receiving saline solution at a dose of 30 ml/kg, the results showed that the mean lactate level increased from 1.06 to 1.99 mmol/l, corresponding to an increase of 0.93 mmol/L after LRS administration, though these results were not statistically significant.[14] Recently, another randomized clinical trial demonstrated that among patients undergoing cardiac surgery, the use of LRS did not reduce the risk of major adverse events over the following 90 days.[16] Currently, there is diverse ongoing clinical research regarding the use of crystalloid solutions and their impact on acid-base status, intra- and extracellular water content, plasma electrolyte compositions, and organ function. This study had important limitations, such as the fact that biochemical parameters of ALT/AST or ALP were not taken in all patients before, during, and after the invasive procedure. Another limitation is that currently, only the RUCAM method is available to evaluate the causality of DILI.

Overall, in clinical practice, it is important to look for all possible triggers of acute hepatic failure, to perform an initial analysis of the adequate function in lactate metabolism, before starting the infusion of lactate-containing crystalloids to avoid adverse clinical outcomes. As a last resort, in patients with acute hepatic failure with no evident cause, all medications or solutions that could be associated with this condition should be evaluated and suspended until the liver function or clinical status is resolved or restored.

CONCLUSIONS

These cases highlight the importance of addressing lactic acid and liver enzymes during the ICU stay of patients who underwent cardiac surgery before starting lactate-containing crystalloid infusion. An initial analysis of patients' lactate

metabolism function should be performed to prevent adverse clinical outcomes related to hyperlactatemia and its associated mechanisms. In cases where acute hepatic failure has been identified without an obvious cause, all medications or solutions that may be associated with this condition should be evaluated and suspended until liver function or clinical status is resolved or restored.

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REVIEW ARTICLE

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Ortner's syndrome secondary to penetrating aortic ulcer. Case report and literature review

Síndrome de Ortner secundario a úlcera penetrante aórtica. Reporte de un caso y revisión de la literatura

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ABSTRACT

Acute aortic syndrome is defined as an acute process in the aortic wall caused by disruption of the medial layer to a varying degree with the risk of aortic rupture and other complications. A penetrating aortic ulcer is included in the acute aortic syndrome and represents the 2-7% of the acute aortic syndrome presentations. With progression, it leads to intramural hemorrhage, the formation of pseudoaneurysm with great risk of rupture. We present a case of a 65-year-old patient with an atypical presentation of penetrating aortic ulcer in the aortic arch associated with intramural hematoma, pseudoaneurysm and Ortner's syndrome that required thoracic endovascular aortic repair, which presented complication of endoleak type IA that was managed with the strategies "wait and see".

Keywords: acute aortic syndromes, Ortner's syndrome, penetrating aortic ulcer.

RESUMEN

El síndrome aórtico agudo se define como un proceso agudo en la pared aórtica causado por la ruptura de la capa medial en mayor o menor grado, con riesgo de rotura aórtica y otras complicaciones. La úlcera aórtica penetrante se incluye en el síndrome aórtico agudo y representa 2-7% de las presentaciones de este síndrome. La úlcera aórtica penetrante puede ocasionar una hemorragia intramural, la formación de pseudoaneurisma, lo que conlleva a un gran riesgo de ruptura. Presentamos el caso de un paciente de 65 años con una presentación atípica de úlcera aórtica penetrante en el arco aórtico asociada a hematoma intramural, pseudoaneurisma y síndrome de Ortner que requirió reparación aórtica endovascular torácica, la cual presentó como complicación una endofuga tipo IA que se manejó con las estrategias "ver y esperar".

Palabras clave: *síndrome aórtico agudo, síndrome de Ortner, úlcera aórtica penetrante.*

INTRODUCTION

Acute aortic syndrome (AAS) is defined as an acute process in the aortic wall caused by disruption of the medial layer to a varying degree with the risk of aortic rupture and other complications.[1-3]

Penetrating aortic ulcers (PAU) were initially described by Shennan in 1934[4] and after his description the PAU is integrated into AAS. Shumacker and King reported the first operative repair of a ruptured descending aorta secondary to a penetrating aortic ulcer in 1959.[5] The clinical and pathologic entity of penetrating aortic ulcers was established, until 1986

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by Stanson.[6] Since that time, the body of literature on this disease has increased significantly.

PAU fits into a spectrum of AAS consisting of classical dissections, intramural hematoma (IMH), limited dissection and iatrogenic/traumatic transection.[7] PAU may be located in the ascending aorta (type A PAU), in the descending thoracic aorta (type B PAU) or abdominal aorta. Simple isolated PAU may be asymptomatic and incidentally detected through imaging or may present with chest, back or abdominal pain.[8,9] Rarer presentations include Ortner's syndrome (recurrent laryngeal nerve palsy due to aortic pathologies),[10] hemopericardium[11] and hemoptysis.[12,13]

The purpose of this report is present an atypical presentation of PAU in aortic arch associated with pseudoaneurysm and Ortner's syndrome that was repaired by means of thoracic endovascular therapy, which in turn, presented endoleak type IA that was managed conservatively.

CASE REPORT

A 65-year-old patient with history of hypertension, chronic obstructive pulmonary disease, non-insulin dependent diabetes, obesity, hyperlipidemia and past medical history of smoking was referred to our emergency room for evaluation of thoracic pain where was implemented the rapid chest pain protocol. The patient referred a sudden pain in the mid-chest without radiation accompanied by dysphonia began three days prior to arrival and had been progressively worsening. He described the pain as vague in sensation, non-radiating, and associated with dysphonia and denied having fevers, shortness of breath. On examination, the patient was hemodynamically stable, with normal heart rate (88 bpm) and rhythm, no cardiac murmurs, respiratory rate of 18, pulmonary examination without abnormalities, pulse present and normal in upper and lower extremities. The blood pressure 142/90 without difference between left and right arm.

His initial workshop showed a normal cardiac enzyme, dimero-D, and the rest of tests unremarkable. The Chest X-ray reported atherosclerotic thoracic aorta that prompted a computed tomography angiography (CTA) of chest was per the "acute aortic syndrome protocol". A chest computerized tomography (CT) scan showed a PAU 1.2 cm distal to the origin of the left common carotid artery and immediately proximal to the left subclavian artery; also, a large pseudoaneurysmal sac measuring 63 mm by 67 mm, was located on the anterior left side of the aortic arch towards the wall chest *(Figure 1)*.

With the finding in the CTA and the high risk for rupture the Heart Team recommended and an urgent intervention, and because the patient's EuroSCORE was 13, and predictive mortality was 41.12%, and the anatomy was adequate the team decide to perform a thoracic endovascular aortic repair. The team approached the aortic arch pseudoaneurysm repair after achieving general anesthesia, through a left femoral artery approach, an endoprosthesis was introduced under fluoroscopic control and controlled hypotension. An endoprosthesis Valiant™ Thoracic Stent Graft Captiva (Medtronic Italia S.p.A.Via Varesina, 162, 20156 Milano) with a diameter of 26 mm and a length of 100 mm, with an oversizing of 20% was chosen. The endoprosthesis was deployed in such a way that the free flow was on the origin of the left common carotid artery *(Figure 2)*. The procedure was carried out without any significant problems, but the final angiogram showed an evident small type IA endoleak that partially refilled the pseudoaneurysm. Patient's pain resolved soon after placement of the stent graft. A CT scan, performed seven days later, confirmed the presence of a small endoleak with slow pseudoaneurysm refilling. The postoperative period was event free, and the patient was discharged on day eight. A follow-up at one month after the procedure, suggested progressive thrombosis of the pseudoaneurysm sac and, at three months, demonstrated occlusion of the pseudoaneurysm with complete resolution of the endoleak. Six months later, an examination done by our division found the patient to be asymptomatic and a routine CT showed the endoprosthesis positioned correctly and resolution of the endoleak and absence of intramural haematoma due to reabsorption *(Figure 3)*.

DISCUSSION

The AAS are a constellation of life-threatening medical conditions, including classic acute aortic dissection, IMH, PAU, which share common pathophysiological pathways,

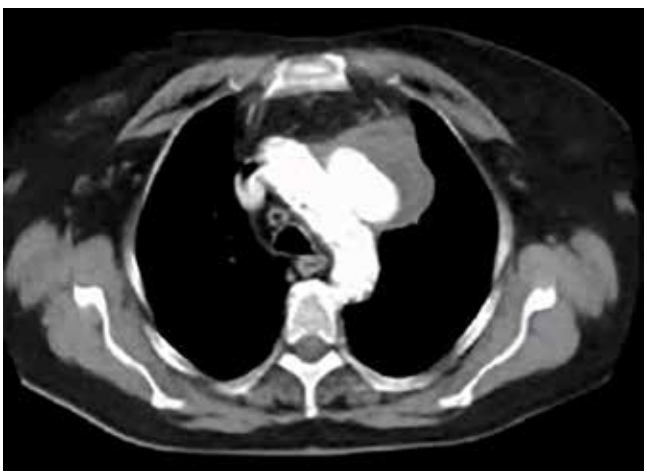

Figure 1: Computer tomography angiography at time of admission showed a penetrating ulcer 1.2 cm distal and pseudoaneurysmal sac measuring 63 × 67 mm, on the anterior left side of the aortic arch towards the wall chest.

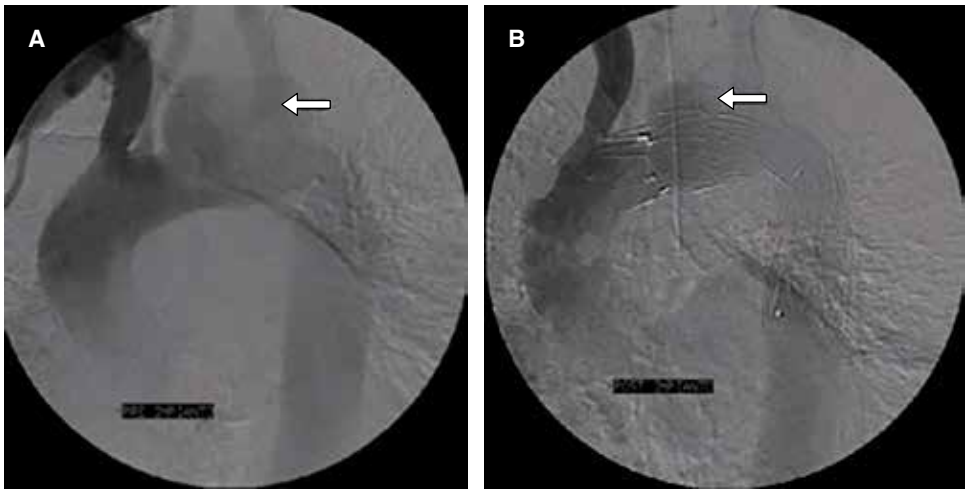

Figure 2:

A) Aortic arch angiogram showing the pseudoaneurysm. **B)** Angiogram post TEVAR deployment demonstrating full coverage of pseudoaneurysm alongside aortic arch visualizing contrast leak inside aneurysm sac.

clinical characteristic, and diagnostic and therapeutic challenges.[14] The incidence of AAS is estimated to be 3.5-6 per 100,000 person-years in the general population and up to 10 per 100,000 person-years in the elderly.[15,16] Isolated PAUs are seen in 2.3 to 7.6% of AAS cases and can be identified in all segments of the aorta however they are most common in the descending thoracic aorta (62%). IMH can coexist with PAU in 45% of cases and may develop into progressive aortic dissection or aneurysm.[17,18] PAU may occur in a solitary location or in multiple segments of the aorta; however, when the ascending aorta is involved, rupture or concomitant IMH are more common.[15,19] In a single-institution review of PAU, the incidence of rupture on presentation was 4.1%, and endovascular or open repair was required in 12.9%. The rupture rate has been reported to be as high as 38% for PAU in an acute presentation, which is considerably higher than that seen for aortic dissection.[20]

Anatomically, there are two commonly used classifications for aortic dissection. The DeBakey system categorizes dissections based on the origin of the intimal tear and the extent of the dissection, and the Stanford system divides dissections according to whether the ascending aorta is involved (type A) or not involved (type B), regardless of the site of origin.[21] Similarly, PAU and IMH can be classified into presence (type A) or absence (type B) of ascending aortic involvement. According with the time course of presentation the AAS is divide into acute (< 14 days), subacute (15-90 days) and chronic (> 90 days) phases.[22] In addition, Svensson sub-classified various types of intimal tears that cause aortic pathologic conditions. Class I-IV intimo-medial defects occur without a known external force, while class V lesions are due to iatrogenic or traumatic causes.[23] PAU is a class II intimo-medial defect and constitutes 2-7% of AAS.

The aorta's microstructure, segmental anatomy, and cardiac impulse hemodynamics determine its function and

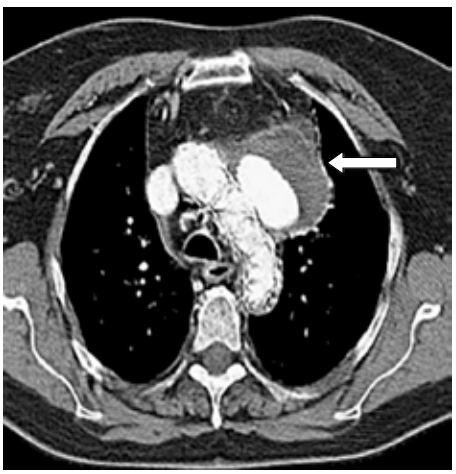

Figure 3:

CTA taken one month after implanting the endoprosthesis with full coverage of PAU, contrast observed inside ulcer corresponding with endo leak type IA.

pathophysiology. The aorta is an elastic artery composed of three inner-to-outer layers –the intima, media, and adventitia– and can be divided into five segments: the root, ascending aorta, arch, descending aorta, and abdominal aorta. Pathologic conditions affecting the aorta are directly influenced by these aortic properties, including its embryologic conotruncal origins.[24] Lesions that involve only the arch or distal aortic segments have a lesser rate of complications in the acute phase but become the dominant concern in the subacute and chronic states.

PAU is an ulcerating lesion most commonly seen in the aortic arch and descending aorta,[25] and affect the intimal layer, with a background of atherosclerotic disease or predisposing factors. It involves an ulcer-like plaque that progressively erodes the intima and burrows through the aortic wall, with remodeling and wall thickening causing a smooth outer bulge. PAU distinguishes itself from common ulcerated atherosclerotic atheroma by burrowing beyond the intima and penetrating the media and its internal elastic lamina, which

separates the two layers. This leads to symptoms and may acutely be associated with a small amount of hemorrhage in the media or contain age-indeterminate thrombus. Given the background of atherosclerotic plaque burden in most affected individuals, the clinical context is important.[25-27] The mechanism of PAU is disruption of the internal elastic lamina than can spread to the media, leading to an IMH, pseudoaneurysm, and if the adventitia is perforated, transmural aortic rupture occurs as the ultimate stage in the natural history.

Although the risks of PAU are well-recognized, their natural history remains poorly defined. The rupture rate has been reported to be as high as 40% (14-40%) for symptomatic presentation.[28,29] In contrast, the natural history of asymptomatic PAU appears more benign, with low rates of rupture and disease progression.[30] The mean age of the patients with PAU are 71.9 ± 6.1 years, more frequent in men (66%), and have the history of smoking (60%), hypertension (89%), hyperlipidemia (62%), and coronary artery disease (42%) are the strongest clinical and laboratory attributes of PAU.[31] The patients are invariably active or past smokers. The same factors hold for IMH. The clinical presentation of PAU is similar to AD except for valvular, cardiac rhythm abnormalities, and ischemic tendencies being seen frequently in the classic aortic dissection. Other atypical findings in the case of PAU are dysphonia, pulse abnormality, signs of a stroke, vascular insufficiency, and end-organ infarction.[32] Pain in the chest, especially radiating to the back, found to be one of the strongest predictors of PAU rupture.[33,34] The radiation of pain may suggest the site of the lesion, anterior chest pain, indicating ascending and pain in back for descending aortic lesions. Intermittent chest pain radiating to the shoulder and back can be another manifestation of the disease, with recurring pain indicating impending rupture.[35] The presence of pleural effusion and a long segment of IMH involvement are frequently seen in symptomatic cases, whereas microembolization events alerted towards the same in asymptomatic cases.[36] Even in the absence of pain, approximately one-third of patients progressed to aneurysm formation over a seven-year follow-up.[25] In many patients, PAU is encountered as an incidental finding devoid of any clinical manifestation whatsoever while investigated for an unrelated condition.

In our case the presentation of hoarseness and dysphonia due to an underlying cardiovascular pathology is a very rare clinical entity known as Ortner's syndrome (OS) or cardiovocal syndrome. The left recurrent laryngeal nerve branches off the left vagus nerve, loops around the ligamentum arteriosum and tracks superiorly between the trachea and the esophagus. In general, injury to left recurrent laryngeal nerve (*i.e.* impingement, stretching, or compression) is more common than injury to the right recurrent laryngeal nerve, likely due to its proximity to the aortopulmonary window and other intrathoracic structures. OS is specific for left recurrent laryngeal nerve injury due to underlying cardiac disease. Although it is commonly associated with severe mitral stenosis (as initially described by Ortner), there are many causes of OS including compression from other vascular (*i.e.* aortic aneurysms, aortic dissections, pulmonary hypertension) or mediastinal (*i.e.* neoplasms) structures.[36-40] Similarly, although the classic symptom associated with OS is dysphonia/hoarseness, there have been several other manifestations of the syndrome described in the literature including aspiration, dysphagia, and shortness of breath.[41]

The diagnosis of penetrating aortic ulcers relies first upon a thorough history and physical examination. The typical patient is elderly with a history of hypertension. These patients can also have a history of coronary artery disease, chronic obstructive pulmonary disease, renal disease, and tobacco use. They typically present with anterior chest or midscapular pain. Similar to aortic dissections, those with anterior chest pain usually have ascending aortic involvement and those with back pain typically have descending aortic involvement. The differential diagnosis with this typical presentation includes acute coronary syndrome, aortic aneurysm, aortic dissection, intramural hematoma, and pulmonary embolism. Physical examination should initially include a review of airway, breathing, and circulation to ensure that the patient is stable. Murmurs indicative of aortic insufficiency typically reflect aortic dissection as opposed to isolated penetrating ulcers, which are focal in nature. Similarly, signs of malperfusion such as neurologic deficits, acute renal insufficiency, visceral vessel compromise, or limb pain with pulse deficit usually occur with dissection as opposed to isolated penetrating aortic ulcers. It is important to note, however, that penetrating aortic ulcers and aortic dissections can occur concomitantly, and therefore, the presence of these signs on physical examination does not exclude a diagnosis of penetrating aortic ulcer. Penetrating aortic ulcers may also be discovered incidentally in asymptomatic patients with imaging performed for other indications.

Radiological imaging is essential to the diagnosis of penetrating aortic ulcers given its similarities to other acute aortic syndromes with respect to clinical presentation. A chest radiograph is the first modality invariably undertaken in a case of chest pain. Patients with IMH and PAU have unremarkable chest radiographs as compared to findings of mediastinal widening with or without pericardial effusion in cases of aortic dissection.[42,43]

CTA is the imaging modality of choice for evaluation of AAS being faster, less invasive, requiring less technical expertise, and ability to reproduce images in any plane with excellent resolution. CTA should be performed after clinical and laboratory evaluation, including cardiac enzymes and D-dimer assay, chest radiograph, and electrocardiogram.[44]

Guidelines regarding indications of CTA (intermediate and high-risk categories), clinical evaluation, and technique to perform CTA in cases of suspected AAS are laid down in 2016.[45] Their main emphasis was to acquire motion artifacts free images, especially of the aortic root with ECG gating. End-systolic versus end-diastolic acquisition depends on the patient's heart rate and the number of the detector array. Recommendations included coverage limited to thoracic aorta, the addition of a non-contrast sequence to detect any associated hematoma, and targeting 250 HU or more attenuation value in the arterial phase. The intimal flap of dissection and associated intramural hematoma is not evident on aortography as seen on CTA. Instead, indirect signs like medial displacement of intimal calcification can be a clue for the same.[46] On CTA, the distinction between true and false lumen can be made reasonably; however, it can be tough in cases where the entire aorta is not included in the scan. The interface between intensely enhancing true and crescentic false lumen can give a beak-like morphology. Acute cases may show outer wall calcification and convex flap morphology towards the true lumen. Transesophageal echocardiography can also be used for diagnosis with a reported high sensitivity and specificity, although its invasive nature and need for a skilled operator are relative disadvantages.[47]

The distinction between PAU and aortic dissection (AD) is vital with the site of the lesion, presence of intramural hematoma, and intimal flap providing a good demarcation improved by dynamic contrast-enhanced imaging.[44] PAU is seen on CTA as contrast filled outpouching or crater-like morphology, ranges in size from few millimeters to 2.5 cm, depth up to 3 cm, are often multiple.[24] There is invariable surrounding IMH and medially displaced calcified intima. A study by Mayo Clinic confirmed this association to the tune of 80 percent.[48] Hyperdensity in PAU on non-contrast study denotes intimal hematoma, an indicator of acute and potentially unstable state warranting prompt intervention.[49,50] The adjacent aortic segment is invariably thickened with some degree of enhancement. PAU usually does not extend beyond the aortic contour, latter being suspicious for rupture, associated hematoma or Subintimal pseudoaneurysm formation.[38] Magnetic resonance imaging (MRI) appearance is akin to the area of flow void showing flow-related enhancement on time-of-flight sequence. Increasing the TE would further enhance the detection of sluggish flow in the ulcer crater. Nonfat sequences were technically less demanding and more accurate than fat saturation sequences and even CTA.

PAU needs to be differentiated from both intramural blood pool and ulcer-like projection, with the former having a wider diameter and intimal atherosclerotic changes and the latter is commonly encountered on follow up imaging in patients with the normal aorta. The disruption of the internal elastic lamina is the key histological finding in cases of PAU, which can be seldom demonstrated. PAU is most commonly seen in descending thoracic aorta followed by abdominal aorta and arch in decreasing order of frequency.

PAU diameter of 20 mm and depth of 10 mm when taken as cutoff, predicted disease progression, suggesting early surgical intervention reasonably. PAU has the worst prognosis in cases of rupture, leading to hemomediastinum and or hemopericardium. Likewise, rupture at initial presentation and maximum aortic diameter predicted the failure of medical treatment.

The occurrence of PAU with IMH generally leads to a progressive disease course with a higher likelihood of catastrophic consequences like aortic rupture and dissection.[7,33] These patients usually belong to an older age group and show involvement of the proximal thoracic aorta. The predictors of disease progression were pain despite expectant treatment, increase in pleural effusion, and disease confined to the proximal thoracic aorta. A higher subset of symptomatic patients explained the same. The presence of pain, hemodynamic instability, suboptimal response to medical treatment, IMH thickness 11 mm or more, periaortic hematoma, and associated PAU beyond a particular dimension are all predictors for rupture.

As with other forms of AAS, medical therapy to optimize blood pressure and heart rate, and reduce aortic wall stress is required to initially treat patients with PAU and IMH. Intravenous beta-blockers and non-dihydropyridine calcium channel blockers are used to keep the blood pressure between 100 to 120 mmHg, and heart rate between 60 and 80 bpm.[49,50]

Adequate pain control is also an important consideration, as uncontrolled pain may result in sympathetic nervous system-mediated heart rate increase.[49] As with AD, patients presenting with complicated type B PAU and IMH should be considered for surgical management. Complicated disease is indicated by persistent or recurrent pain despite adequate control of hypertension, uncontrolled hypertension, aortic expansion on repeat imaging, hemodynamic instability, organ ischemia, maximum aortic diameter > 55 mm and rupture. In addition, surgical repair is indicated for any of the following features: PAU base > 20 mm and depth > 15 mm, IMH with significant periaortic hemorrhage.[49,51-53]

In our case the clinical presentation with symptomatic PAU-IMH associated with pseudoaneurysm and the information that gave us the image studies, there was no doubt that the patient required an emergent surgical therapy. The team decided to realize a TEVAR because of the high mortality predicted by EuroSCORE in our patient and the great results of TEVAR in the last years. When surgery is considered in the PAU with IMH, endovascular techniques are considered first-line therapy.[15,54] Endovascular technical success has been

reported at, or close to, 100% in a number of studies.[31,55-57] In hospital/30-day mortality post TEVAR for PAU is estimated at 4.8%.[31] Overall survival at 1, 5 and 10 years has been reported at 93%,[57,58] 72-84%[31,59] and 60-70%,[57,58] which is reflective of the comorbidities in patients with PAU. The long term aortic-related survival rates have been reported between 96-100%.[58,60]

The complication rate of TEVAR has been estimated to be as high as 38%, and the most common complications include endoleak, upper extremity limb ischemia, cerebrovascular ischemia, spinal cord ischemia, and post-implantation syndrome.[61] Endoleaks are the most common causes of TEVAR reintervention and are defined as functional failures in the deployed endografts, allowing for the persistent flow of blood into the excluded aneurysm sac. They are traditionally divided into five types based on the origin. Type I, or implantation, endoleaks occur at the stent-graft landing sites. These are due to inadequate apposition of stent-graft with arterial wall of the proximal (IA) or distal (IB) attachment sites of the deployed endograft.[62] Due to this direct pressure, there is always risk of rapid aneurysm enlargement and rupture. This can be due to many factors, including preoperative mural thrombus, vessel calcification, branching vessels, graft migration, or incorrect sizing of stent-graft materials. Type I endoleaks have been described as occurring immediately postoperatively so a more practical way to classify this type of endoleak is named them into direct endoleaks.

Type II, or backflow, endoleaks are caused by blood entering the aneurysmal sac in a retrograde fashion via patent branching vessels.[62] Often excluded by the endograft, segmental arteries can have retrograde flow via internal thoracic and intercostal arteries, contributing to endoleak and aneurysmal growth. Type III, or junction, endoleaks are due to extravasation of blood at stent-graft component junction points (IIIa) or due to graft fabric tear, suture breakage, or component fracture (IIIb).[62,63] Type III can also be observed as both early and late onset depending on contributing factors. Type IV, or porosity, and type V endoleaks are extremely rare after TEVAR. Type IV is caused by fabric porosity, which allows for the outflow of plasma into the excluded aneurysm. Type V is due to endotension or aneurysmal expansion without radiological evidence of another source.

Completion angiograms can detect early types I and III. Delayed images can show type II endoleaks. Contrast-enhanced CT is the gold standard for the detection of endoleaks on subsequent visits. Duplex ultrasound can also detect an endoleak. It is economical, free of radiation and contrast. Besides detecting the endoleak, it can also provide information on different types of flow and directions in these endoleaks. Its limitation is operator-dependent.

In a review of 27 studies evaluating TEVAR for aortic dissection, reintervention was required in 15% of cases, with 33% of those due to an endoleak.[64-66] In all indications for TEVAR, endoleaks have an estimated incidence of 3.9-15%. Data are conflicting as to which type of endoleak is most common. Type I and type II endoleaks are considered the most prevalent by several studies. The overall incidence of early and late type I endoleaks is thought to be up to 20%, and with intraoperative incidence at a rate of 3-7%. Once a decision is made to intervene, management of endoleaks varies by type. Type I endoleaks are best handled by extending the proximal and distal portions of the stent graft to include non-diseased portions of the aorta and by using endoanchors, which securely fasten edges.[67] However, the extension of the proximal or distal edges of grafted stents requires consideration of the risk associated with coverage of the left subclavian artery, left carotid artery, or spinal segmental arteries.

In our case the most common complication of the TEVAR appears immediately during the procedure, like early Type IA endoleak. Followed more recent studies the type IA endoleak most imperatively treated intraoperative with simple dilatation of the stent with balloon angioplasty (25 to 30 mm balloon), with the placement of a proximal cuff, Palmaz stent placement, endoanchors, or the embolization and coiling of the aneurysmal sac but these techniques are not always possible for technical and anatomical challenges.[68-71] No one of the treatments proposed was usable for the low refilling flow, that our case presented so we decide to follow the strategy wait and see, and to monitor in the course of time the development. We observed a progressive thrombolization and a complete resolution of the endoleak.

In conclusion, PAUs and IMH are often seen together or in conjunction with pseudoaneurysm or aortic dissection. The clinical presentation of PAU is variable but always must be in differential diagnosis of AAS. When diagnosed in the symptomatic patient, these complex aortic pathologies represent a potentially life-threatening medical condition. Prompt identification, medical management, and patients' selection for intervention are critical components of care, along with long-term surveillance. The TEVAR is considered first-line therapy in the patients with Type B AAS, which have an excellent result but it is not free of complications. Endoleaks are the most common complications following TEVAR and the management remains one of the inherent challenges to endovascular treatment. Proper planning and appropriate selection of stent-graft can prevent most of these endoleaks.

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EXPERTS' PERSPECTIVES

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The narrow window of TRISCEND II: a step forward but how far?

La estrecha ventana del TRISCEND II: un paso adelante, ¿pero qué tan lejos?

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ABSTRACT

The TRISCEND II trial seemingly demonstrates the superiority of transcatheter tricuspid valve replacement over medical treatment for patients with severe functional tricuspid regurgitation. However, closer examination reveals substantial methodological vulnerabilities, including a contentious 2:1 randomization ratio favoring device allocation and lack of blinding. While improvements in quality of life and NYHA functional classification were reported, no significant differences were observed in hard endpoints such as mortality, heart failure hospitalization, right ventricular device implantation or cardiac transplantation. The subjective nature of quality of life assessments using the Kansas City Cardiomyopathy Questionnaire introduces bias. The use of soft endpoints (e.g. quality of life, symptom severity) may artificially inflate the number of events, thereby compromising the trial reliability. Furthermore, the study's demographic composition, predominantly comprising patients with atrial functional tricuspid regurgitation, limits generalizability. Notably, significant device-related complication rates necessitate thorough risk-benefit analysis. In conclusion, the trial fails to provide generalizable results for the majority of patients with severe functional tricuspid regurgitation and is susceptible to bias. Prolonged follow-up is required to assess hard endpoints and mitigate bias induced by soft endpoints.

RESUMEN

El ensayo clínico TRISCEND II sugiere beneficios del reemplazo valvular tricuspídeo percutáneo sobre el tratamiento médico en pacientes con insuficiencia tricúspide funcional severa. Sin embargo, un análisis más detallado revela vulnerabilidades metodológicas significativas. La relación de randomización 2:1 a favor del dispositivo y la falta de cegamiento (estudio no ciego, abierto) introducen sesgos. Aunque el estudio reportó mejoras en la calidad de vida y clasificación funcional de la NYHA, no hubo diferencias significativas en endpoints duros como mortalidad, hospitalización por falla cardíaca, implante de dispositivos de asistencia ventricular derecha o trasplante cardíaco. La medición de la calidad de vida mediante el cuestionario Kansas City Cardiomyopathy Questionnaire es subjetiva y susceptible a sesgos. La inclusión de endpoints blandos (como calidad de vida o la presencia, ausencia o intensidad de la sintomatología) puede inflar artificialmente el número de eventos, comprometiendo la rigurosidad del estudio. La composición demográfica del estudio, predominantemente pacientes con insuficiencia tricúspide funcional atrial, limita la generalizabilidad de los resultados. Los índices significativos de complicaciones en el grupo del dispositivo requieren una evaluación exhaustiva en el análisis de riesgo-beneficio. En resumen, el estudio no demuestra resultados generalizables para la mayoría de los pacientes con insuficiencia

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tricúspide funcional grave y está sujeto a sesgos. Se requiere un seguimiento más prolongado para evaluar endpoints duros y eliminar el riesgo de sesgos inducidos por endpoints blandos.

Keywords: catheterization, heart valve disease, heart valve prosthesis implantation, tricuspid valve, tricuspid valve insufficiency.

Palabras clave: *cateterismo, enfermedad valvular cardíaca, implante de prótesis valvular cardíaca, válvula tricúspide, insuficiencia de la válvula tricúspide.*

An examination of TRISCEND II trial outcomes reveals an apparent advantage of transcatheter tricuspid valve replacement (TTVR) over medical treatment in patients with severe functional tricuspid regurgitation (TR) at two years of follow-up,[1] but closer scrutiny exposes substantial methodological vulnerabilities.

Randomized controlled trials (RCTs) constitute the gold standard for assessing medical interventions, as randomization ensures the equitable distribution of known and unknown confounding variables across treatment arms, mitigating selection bias.[2,3] In TRISCEND II trial, the 2:1 randomization ratio favoring device allocation is particularly contentious, as it may contravene established ethical principles and introduce bias, thereby necessitating rigorous reassessment of the study's implications.

This trial's primary composite outcome showed favorable results for the device plus medical treatment cohort, mainly driven by improvements in quality of life, NYHA functional classification, and 6-minute walking test performance. However, no significant differences were observed in hard endpoints [mortality, heart failure hospitalization (HFH), right ventricular (RV) assistant device implantation, or cardiac transplantation], highlighting the importance of contextualizing these results.

Cardiovascular death and HFH are unequivocal, binary events characterized by high objectivity and minimal bias, making them quintessential hard clinical endpoints. Hard endpoints are based upon quantifiable, objective criteria unaffected by personal opinions. On the contrary, soft endpoints, such as quality of life or symptoms, albeit crucial in clinical practice, are prone to unintended bias in unblinded trials due to reliance on physician and patient interpretation and the physician's therapeutic intent. Blinding has long been recognized as the gold-standard solution to mitigate this bias in measuring these endpoints. Unfortunately, this kind of trials is quite difficult to blind.[4]

Considering these factors, what significance do they hold in relation to the TRISCEND II study? Particular mention should be noted about the quality of life in this trial, which was measured by the Kansas City Cardiomyopathy Questionnaire (KCCQ). This tool, the KCCQ-driven quality of life assessment is susceptible to critique due to its inherently subjective character. Although the KCCQ is a widely recognized, validated tool for evaluating health status in heart failure patients,[5] its subjective design inherently limits its objectivity, potentially introducing biases due to patient self-reporting.[6] Likewise, as mentioned above, the symptom-based NYHA functional classification may introduce interpretative biases. As a matter of fact, evidence suggests that unblinded evaluations can skew subjective (soft endpoints) outcomes. Research suggests that simply communicating a treatment plan, such as ruling out surgery, can profoundly impact patient symptoms. Furthermore, the placebo effect associated with invasive procedures, like intracardiac device implantation, can substantially influence patient-reported outcomes, including lifestyle adjustments and symptom alleviation. The problem is that the *power of faith healing* influences scientific research in unblinded trials.[4] Another further potential bias concern emerges in these trials when treatment is compared to a control group where standard treatment is omitted. This phenomenon, known as *subtraction anxiety*, refers to the anxiety that arises when a patient requires routine treatment but does not receive it, generating anxiety for the physician and patient due to unmet treatment expectations. This situation can create a need to alleviate tension through action, triggering urgent interventions, or even urgent hospitalizations. Consequently, this may compromise the objectivity of clinical trials and medical decision-making, particularly in routine procedures where treatment expectations are high. Subtraction anxiety plays a pivotal role in the control arm of unblinded trials. Unblinded trials of proven beneficial interventions are particularly susceptible to subtraction anxiety in the control group.[4]

Conversely, unlike soft endpoints, TRISCEND II revealed no statistically significant differences in objective, hard endpoints, specifically mortality, HFH, reoperation, and RV assistant device implantation or cardiac transplantation). Even reoperation or reintervention fall short of these criteria, due to the multitude of factors that may prevent patients from undergoing repeat procedures, thereby introducing bias. Therefore, the primary composite endpoint must be objective and impervious to bias from unblinded assessment: namely, cardiovascular death, and at a lesser extent, HFH. Perhaps, the same can be said about HFH for non-treated patients by an already known percutaneous treatment. The inclusion of soft endpoints, as occurred in TRISCEND II, may artificially inflate the number of events, undermining the rigor and reliability of this trial.

Another crucial aspect warranting clarification is the TRISCEND II demographic composition, predominantly characterized by atrial functional TR. This is evidenced by the high prevalence of atrial fibrillation (> 90%), only mildly impaired tricuspid annular plane systolic excursion (TAPSE) values (16.3-15.4 mm), mild-to-moderate pulmonary artery systolic pulmonary hypertension (PASP: 38.6-37.6 mmHg), and preserved left ventricular ejection fraction (LVEF) values (54.4 and 54.3%). Notably, fewer than 34 and 31% of patients had undergone prior valvular heart interventions including left-sided valvular heart diseases. Collectively, these characteristics suggest that the study population primarily comprised patients with atrial functional TR, a subgroup known for its relatively favorable long-term prognosis and outcomes. Consequently, TRISCEND II findings may have limited generalizability, applying to a highly specific subset of patients with severe functional TR, potentially comprising less than 25% of all secondary or functional TR cases.[7] To mitigate interpretative biases and ensure translational relevance in clinical practice, it is essential to recognize this critical limitation.

The device arm's significant complication rates up to 10.4% bleeding at 31-days and 17.4% permanent pacemaker implantation at 1-year demand thorough evaluation in the risk-benefit analysis, particularly when balancing these adverse events against enhancements in quality of life and symptom alleviation.

The 1-year site-reported serious adverse event profile reveals a significant disparity, with a 4.2% incidence of RV dysfunction in the device arm versus 0% in the control arm. Preexisting RV dysfunction may contribute to this increased risk, as Laplace's law predicts elevated RV wall stress post-implantation of TTVR.[8] However, subgroup analyses are requisite to confirm this potential association.

In summary, the evidence suggests that, although well-conducted, this trial ultimately fails to demonstrate generalizable results applicable to the vast majority of patients with severe secondary or functional TR. Furthermore, this trial is highly prone to bias, and longer follow-up can enable assessment of hard primary endpoints, while eliminating the risk of bias induced by soft endpoints, such as quality of life and symptoms.

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CASE REPORT
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Extracorporeal cardiopulmonary resuscitation for failed cardiopulmonar resuscitation: the future has arrived. Case report

Resucitación cardiopulmonar extracorpórea en caso de reanimación cardiopulmonar fallida: el futuro ha llegado. Reporte de caso

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ABSTRACT

Cardiopulmonary resuscitation represents the gold standard in the management of cardiac arrest and/or sudden death; however, there is a significant number of potentially recoverable patients who do not respond to this treatment. Recent evidence of the utilization of percutaneous extracorporeal circulation as the last resource for the resuscitation of potentially recoverable patients in whom traditional cardiopulmonary resuscitation fails has shown promising results. We present a case of success of extracorporeal cardiopulmonary resuscitation for refractory cardiac arrest.

Keywords: cardiac arrest, sudden death, cardiopulmonary resuscitation, extracorporeal cardiopulmonary resuscitation, extracorporeal membrane oxygenation, extra-corporeal life support.

RESUMEN

La reanimación cardiopulmonar representa el estándar de oro en el manejo del paro cardíaco y/o muerte súbita; sin embargo, existe un número significativo de pacientes potencialmente recuperables que no responden a este tratamiento. Evidencias recientes de la utilización de la circulación extracorpórea percutánea como último recurso para la reanimación de pacientes potencialmente recuperables, en quienes la reanimación cardiopulmonar tradicional falla, han mostrado resultados prometedores. Presentamos un caso exitoso de reanimación cardiopulmonar extracorpórea para paro cardíaco refractario.

Palabras clave: *paro cardíaco, muerte súbita, reanimación cardiopulmonar, reanimación cardiopulmonar extracorpórea, oxigenación por membrana extracorpórea, soporte vital extracorpóreo.*

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Cardiac arrest (CA) defined as the loss of mechanical function of the heart is a frequent cause of death and a major public health problem with an incidence in North America and Europe that approximates 50 to 100 cases per 100,000.[1,2] In Hospital Cardiac Arrest (IHCA) has a reported incidence in Europe of 1 to 5 per 1,000 admissions with an overall survival rate of 23%.[3] Response to IHCA or ventricular fibrillation has developed over time and now triggers the presence of a team of specially assigned and trained first responders. Different cardiopulmonary resuscitation (CPR) techniques have evolved based on compelling scientific evidence, establishing universally standardized processes that have guaranteed the best possible results; always depending on the clinical scenario of each patient.

Modern cardiac surgery was developed primary by the invention of the heart-lung machine by Dr. John Gibbon in 1953, which allows full body perfusion with an arrested heart.[4] This technology has evolved and has benefited from the miniaturization of both equipment and cannulas for vascular access, as well as the manufacture of better membranes for gas exchange that can support patients properly for long periods of time.

When consulted to treat individuals with history of "in hospital" sudden death (SD) or CA, especially "a witnessed event" in patients who, both due to their age and general health condition could be categorized as "potentially recoverable", abandoning conventional CPR after several failed attempts; today represents "not having offered all the available therapeutic options". With the development of percutaneous cannulas and compact extracorporeal circulation systems, as well as the new multidisciplinary teams of health professionals trained to perform these procedures, we can support and rescue patients with peripheral cardiopulmonary bypass frequently using extracorporeal membrane oxygenation (ECMO) creating a new window of therapeutic opportunity.[5]

Also patients with terminal heart or lung diseases who develop cardiorespiratory arrest in which conventional CPR fails and fully rescued by the successful application of cardiopulmonary bypass can allow us in case of heart disease to reconvert the cardiac ECMO circuit towards sophisticated ventricular support devices either for bridge to heart transplantation and/or for destination therapy; and in the case of terminal pulmonary patients, they can remain on cardiac ECMO or reconvert the system to respiratory ECMO so that the system allows the bridge to lung transplantation.[6]

CASE DESCRIPTION

We present herein the case of a 63-year-old female patient with past medical history of type 2 diabetes mellitus, hypothyroidism, and anterior myocardial infarction (AMI) in 2014. In 2023, she presented with a second AMI associated with cardiogenic shock. She was treated with percutaneous coronary intervention, intra-aortic balloon pump (IABP), endotracheal intubation and vasopressors. At the same time, she was diagnosed as bilateral pulmonary emboli. After 11 days, she was discharged at home stable, with left ventricle ejection fraction (LVEF) of 20%, treated with conventional medical therapy for heart failure with reduced ejection fraction, oral anticoagulation and supplementary oxygen.

In early June 2024, she arrived at the emergency room after one week of suffering progressive dyspnea, orthopnea, and swelling of the lower limbs. Cardiopulmonary examination with bilateral hypoventilation at lung auscultation and fine rales in the right lung. Cardiac auscultation with systolic murmurs in mitral and tricuspid foci. Rest of the physical examination without abnormalities.

The electrocardiogram evidenced irregular rhythm with ventricular pace of 55 bpm, with absence of P waves. Transthoracic echocardiogram showed LVEF of 25%, PSAP (pulmonary artery systolic pressure) 65 mmHg, without organized auricular activity, ventricular dyskinesia, severe mitral and tricuspid insufficiencies. Blood labs with BNP (B-type natriuretic peptide) 2,751, rest without alterations.

Thoracic posteroanterior X-ray presented diffuse interstitial thickening, suggestive signs of pleural effusion and cardiomegaly. She was diagnosed with heart failure NYHA III and severe mitral and tricuspid insufficiencies.

Conventional medical management was initiated and further on an automated implantable cardioverter-defibrillator (AICD) was successfully placed. Despite initial management,

Figure 1:

Extracorporeal cardiopulmonary resuscitation (ECPR) with a Cardiohelp System (Getinge AB, Sweden).

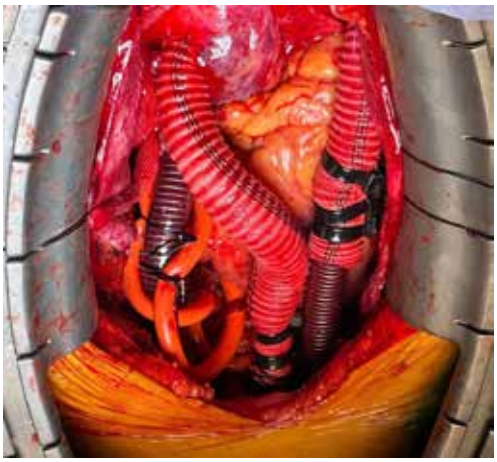

Figure 2: Central cannulation for biventricular support.

the patient deteriorated and presented with electromechanical dissociation (despite AICD) and resuscitation was achieved with the placement of and IABP, medical management and mechanical ventilation.

Twenty-four hours later, after being stable, she presented "witnessed" sudden ventricular fibrillation non-responsive to the AICD therapy and conventional CPR. After 40 minutes of failed CPR, extracorporeal cardiopulmonary resuscitation *(Figure 1)* was successfully established by removing the IABP in the right femoral artery for arterial outflow access and a left femoral vein previous central line for the extracorporeal life support (ECLS) venous inflow. After 8 hours we performed a neurological evaluation and no evidence of neurological damage was observed. ECLS flows were enough (average 3 liters/min) to sustain adequate organ perfusion; however, echo showed practically no left ventricular function.

With the patient's cardiac medical history and the recent events, we decided that her best option was to upscale the circulatory assistance and she underwent the successful implant of biventricular mechanical para corporeal cardiac support with a dual Centrimag axial flow system (Levitronix GmbH, CH-8048 Zurich, Switzerland).

Central Cannulation was performed under cardiopulmonary bypass (using the femoral ECLS device as CPB), with angled 32 Fr cannulae for the left and the right atrium and 12 Fr grafted cannulae for the aorta and pulmonary arteries *(Figures 2 and 3)*.

The patient had an uneventful recovery, she was extubated, starting to ambulate awaiting further evaluation and be listed for cardiac transplantation.

COMMENT

It has been a long way since the first publication of the Advanced Cardiovascular Life Support program (ACLS) by the American Heart Association in 1975.[7] CPR procedures have scientifically evolved and it's results have shown today that close to 25% of patients suffering from cardiac arrest in a hospital environment can be saved. Likewise, the widespread instruction of universal CPR techniques for health and non-health professionals in the prehospital environment have resulted in better survival rates.[1,8,9]

Nevertheless, in both scenarios, a subset of patients exists who remain potentially recoverable despite the failure of conventional CPR. Within this subgroup, extracorporeal cardiopulmonary resuscitation (ECPR) has demonstrated remarkable efficacy.[8]

The continuous improvement of cannula for percutaneous peripheral ECLS has provided the opportunity for trained multispecialty professionals to cannulate the patients. Also, it is a known fact that many of these procedures are performed in critically ill patients where the operator skill is important, and even some patients have to be cannulated in the Intensive Care Unit with only ultrasound and/or echo guidance. In the case of ECPR the conditions turn out to be more difficult because the patients are cannulated when undergoing chest compressions and during failed CPR. Initial success will depend on the hospital's cumulative experience with this type of procedures and the 24/7 availability of a "rapid-response team".

In our country, despite the fact that we started the application of ECLS techniques in the early 1990's, it was limited to only a few centers and mainly used for post

Figure 3: Biventricular mechanical extracorporeal cardiac support with a dual CentriMag axial flow system (Levitronix GmbH, CH-8048 Zurich, Switzerland).

cardiotomy and failed angioplasty cases. The COVID-19 pandemic forced us to integrate many more "rapid-response teams" in most large reference centers, and cases multiplied to such numbers that this teams traveled by land or air long distances to rescue critically ill patients and transferred them on ECMO to our and other experienced facilities; thus turning the clinical use of ECLS from the "once in a while monster case" to a routine everyday procedure.[10]

However, and despite our long and extensive experience with cardiopulmonary support and ventricular assist devices, aside from post cardiotomy cases, failed cath-lab procedures and ventricular assist devices implantation, most cases were planned or elective. We had not established before ECPR as a standard 24/7 procedure.

CONCLUSIONS

The case described above demonstrates again the success of ECPR for failed conventional CPR and that can be safely done on a third level general community hospital. We hope that with the implementation of this new program, ECPR success cases will grow and in a near future or Raid Response Team will be able to perform successful ECPR in Non-Hospital Environment as it has been done in other countries.[11]

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Author instructions

Instrucciones para los autores

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