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Surgical technique and challenges of multi-organ procurement in times of COVID-19

Técnica quirúrgica y retos de procuración multiorgánica en tiempos de COVID-19

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ABSTRACT

Mexico performed 1,136 deceased donor kidney and liver transplants in 2019. Due to the SARS-CoV-2 disease pandemic (COVID-19) as of March 2020, all donation and transplant programs were temporarily suspended, so multi-organ procurement decreased by 94% during the second and third quarters of the year. Transplant programs are considered a priority because of their high impact on major public health problems. As a result of a decrease in hospital admissions and occupancy, the National Transplant Center (CENATRA) published a reactivation plan for these programs in June. This plan considers screening measures for all potential donors, including tests such as reverse transcriptase polymerase chain reaction (RT-PCR) and chest tomography (CT), which is why we report in this article the time needed and the feasibility of running these *screening tests* in a clinical case in Yucatan, as well as a review of the surgical technique for explant surgery.

RESUMEN

México realizó 1,136 trasplantes renales y hepáticos de donante fallecido durante el 2019. Como consecuencia de la pandemia por la enfermedad por SARS-CoV-2 (COVID-19), a partir de marzo del 2020 se suspendieron temporalmente todos los programas de donación y trasplantes, por lo cual las procuraciones multiorgánicas disminuyeron en 94% durante el segundo y tercer trimestre del año. Los programas de trasplantes son considerados prioritarios por su gran impacto en los principales problemas de salud pública. Como consecuencia de una disminución de ingresos y ocupación hospitalaria, en junio se publica por parte del Centro Nacional de Trasplantes (CENATRA) el plan de reactivación de estos programas. En dicho plan se consideran medidas de escrutinio a todo potencial donante, así como la realización de pruebas como reacción en cadena de la polimerasa con transcriptasa inversa (RT-PCR) y tomografía (TC) de tórax, motivo por el cual reportamos en el presente artículo el tiempo necesario y la viabilidad de correr estas pruebas de screening en un caso clínico de Yucatán, así como una revisión de la técnica quirúrgica para la cirugía del explante.

INTRODUCTION

Current organ transplantation is one of the most significant advances in modern medicine, being the definitive treatment for many patients with terminal organ failure. The Mexican Institute of Social Security (IMSS) has been at the forefront in this field for several years, concentrating the most significant activity on donation and transplantation in Mexico.[1]

In 2019 in Mexico, 1,136 deceased donor kidney and liver transplants were performed; currently, more than 17 thousand patients are registered on the waiting list to receive a transplant of one of these two organs.[2,3]

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Around the critical situation generated by the COVID-19 pandemic, the National Transplant Center (CENATRA) issued in March 2020 the "Recommendations to the National Subsystem of Donation and Transplantation on the infection associated with SARS-CoV-2", suggesting the temporary suspension of all organ and tissue donation and transplantation programs nationwide, except for zero emergencies and priority allocations. This is in line with other international recommendations published by the Spanish National Transplant Organization (ONT), the Latin American Society of Nephrology and Hypertension (SLANH), the Transplant Society of Latin America and the Caribbean (STALYC), the Pan American Association of Infectious Diseases (API), as well as by the National Central Institute of Ablation and Implant Coordination of Argentina (INCUCAI).[4,5]

As a result, multi-organ procurement in Mexico plummeted 94% during the second and third quarters of 2020 compared to the same period last year, with a total of 15 vs. 280 procurements completed, respectively.[6,7]

Contrary to some perceptions, transplant programs are considered relevant because of their incredible impact on public health problems, such as end-stage renal failure, making them priority programs. For this reason, associated with a decrease in hospital admissions and occupancy due to COVID-19 cases, CENATRA published a plan to encourage the reactivation of donation and transplantation programs in our country in June of this year. In this plan, the internal transplant committee must carry out a diagnosis of the particular epidemiological situation of the establishment. It will evaluate the availability of human, financial, technological, and material resources, COVID-19-free circuits, hospital beds in intensive care Units, and laboratory and cabinet studies (RT-PCR tests and thorax tomography), among others.[8] These last two *screening* studies for SARS-CoV-2 are necessary for both the donor and the potential recipients, which adds complexity to the already laborious logistics.

This article aims to estimate the time necessary to comply with current RT-PCR and chest tomography protocols, their feasibility, and their impact on the donation/transplantation process; we will also analyze the main surgical aspects of multi-organ procurement surgery.

CASE PRESENTATION (Table 1 and Figure 1)

Surgical aspects

The following is a description of the surgical technique with some images and algorithms to facilitate an understanding of the process.

Preparation and field

a. It is mandatory that the surgeon in charge reviews all documentation prior to the incision, especially: certification of loss of life for the disposal of organs and tissues with the time of death equal to that of the cabinet study showing absence of cerebral flow; consent for the disposal of organs and tissues of cadavers for transplantation purposes, with signatures and identifications; the results of negative infectious serologies and finally, if applicable, the consent of the Public Prosecutor's Office.
b. Negative RT-PCR for SARS-CoV-2, ideally 24 hours maximum 72 hours before the surgical event.
c. In cases where available, a chest CT scan should be performed. It should be clarified that an image not suggestive of COVID-19 does not rule out the active disease process.
d. Communication between the surgeon and the anesthesiologist is confirmed for administering medications at the various crucial stages: hemodynamic support during surgery, relaxants to avoid any spinal reflex or Lazarus reflex in the donor, and anticoagulation prior to clamping.
e. Perfusion set ready with at least eight liters of preservation solution and 10 liters of frozen sterile solutions.

Table 1: Schedule of actions carried out.

Day	Time	Event
0	16:00	The Emergency Department reports to the hospital donation coordinator about a 23-year-old male patient with severe cranioencephalic trauma secondary to a car accident 24 hours before his admission; he is found with clinically absent stem reflexes and a cerebral angio-CT scan showing an absence of flow. In a committee session, it was determined that the two kidneys and the liver would be transferred to Mexico City due to the absence of conditions to perform the transplants in the generating hospital
0	17:00	With the support of the Epidemiology Service and the central laboratory of the generating hospital, a COVID-19 oral-nasopharyngeal RT-PCR test was performed
0	19:00	A chest CT scan showed a left pneumothorax, a pleural bypass tube, and bilateral pulmonary contusion areas without data suggestive of SARS-CoV-2 infection
1	05:00	The result of the COVID-19 test by RT-PCR was negative
1	10:00	Proceedings before the Public Prosecutor's Office are initiated
1	17:00	*TIME OUT*: multi-organ procurement surgery by the generating hospital's transplant surgical team to avoid inter-state equipment transfer
1	19:00	Clamping
1	20:00	Transfer of the organs from Merida to Mexico City by plane
2	03:00	Hepatic depinning
2	06:00	Successful completion of liver transplantation
4	10:00	Successful transplantation of both kidneys during the morning of day four (with pulsatile hypothermic perfusion support from the arrival of kidneys on day one; > 72 h of ischemia)

RT-PCR = reverse transcriptase polymerase chain reaction. CT = computerized tomography.

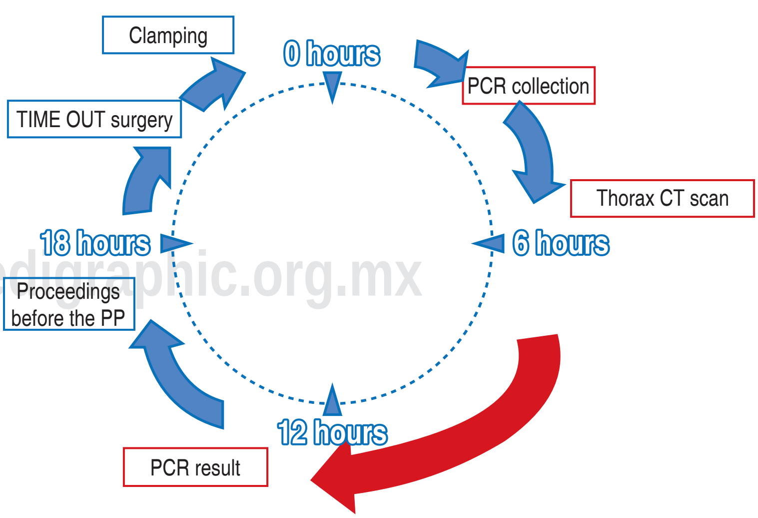

Figure 1:

Hours elapsed between notification and certification of brain death and the various processes culminating in procurement. PCR (one hour after onset), chest CT scan (four hours after onset), PCR result (13 hours after onset), proceedings before the Public Prosecutor's Office (18 hours after onset), start of TIME OUT procurement surgery (20 hours after onset) and aortic clamping (22 hours after onset).
PCR = polymerase chain reaction.
CT = computed tomography.
PP = public prosecutor.

f. Surgical toilet 5 cm above the xiphoid, covering the abdomen to the symphysis pubis, including the middle third of both thighs.

Surgical procedure

a. **Abdominal approach and clinical evaluation.** A cross incision is made, starting with a medial xiphoid incision up to the symphysis pubis and completed with a transverse incision up to the limits of Toldt's fascia. Thoracic enlargement with stereotomy is optional *(Figure 2A)*.
Subsequently, the round and suspensory ligaments are ligated, sectioned, and incised up to a few millimeters proximal to the suprahepatic veins. Examination of the intra-abdominal organs is performed to exclude possible malignant disease *(Figure 2B)*. Clinical evaluation for hepatic steatosis is assessed at this stage, especially if a pathologist is unavailable. The surgeon assesses the coloration, pressing parenchyma, borders, and firmness of the liver *(Figure 2C)*.[9]
b. **Dissection of great vessels and renal exposure.** The parietal peritoneum is incised with electrocautery at the level of the bifurcation of the abdominal aorta. It extends laterally to the cecum to continue along Toldt's fascia, ascending to the hepatic angle *(Figure 3A)*.
Dissection continues (Cattell-Braasch and Kocher maneuver) along the inframesocolic retroperitoneal avascular plane to mobilize and retract the ascending colon medially, mobilization of the duodenum and pancreatic head to expose the Gerota and right renal vein, inferior vena cava and abdominal aorta. The right ureter is identified and dissected *(Figure 3B)*.
At this stage, the superior mesenteric artery is dissected at its origin from the aorta, which emerges above the crossing of the left renal vein to the abdominal aorta, in search of an accessory artery or replacement of the right hepatic artery *(Figure 3C)*.
The contralateral retroperitoneal dissection is performed using the Mattox maneuver, incising the left Toldt's fascia up to the splenic angle, dissection of the retroperitoneal avascular plane exposing the Gerota and the left ureter.
c. **Referral for cannulation.** In preparation for cannulation and Perfusion, the distal segment of the aorta is dissected in search of the inferior mesenteric artery, which is ligated and cut. Similarly, the inferior vena cava is dissected and referred to with umbilical tape at the level of the iliac veins inflow *(Figure 4A)*.
Lateral to the angle of Treitz, the inferior mesenteric vein is identified, dissected,

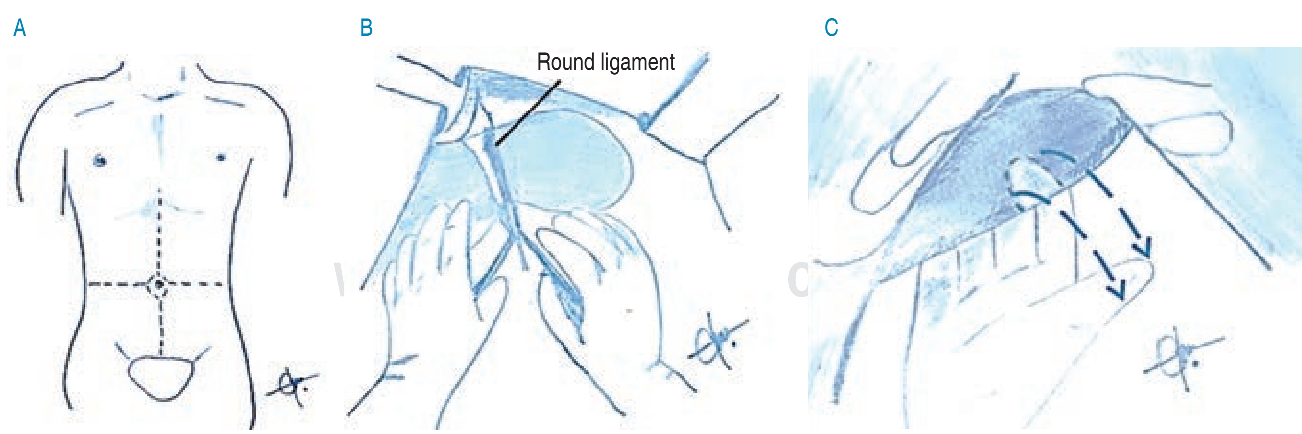

***Figure 2: A)** Cross incision. **B)** Incision of the round and suspensory ligament. **C)** Pressure of the hepatic parenchyma.*

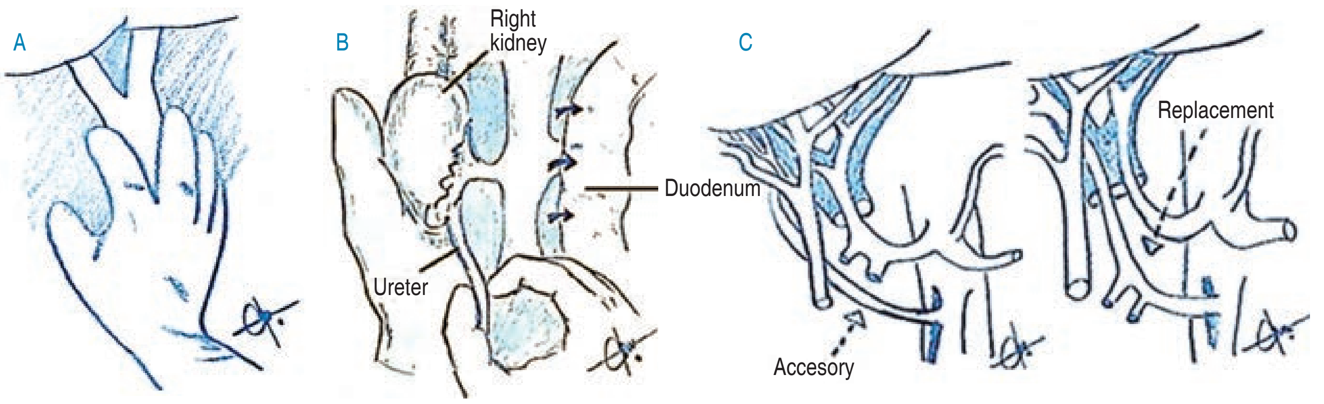

Figure 3: ***A)*** *Abdominal aortic bifurcation dissection.* ***B)*** *Cattell-Braasch and Kocher maneuver.* ***C)*** *Accessory or right-side replacement.*

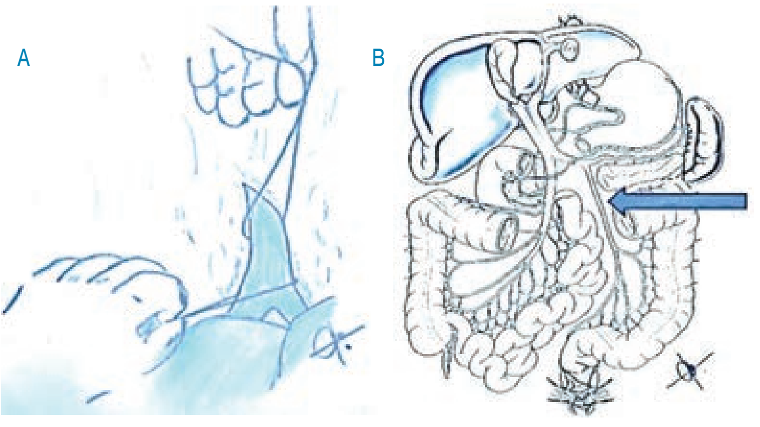

Figure 4: ***A)*** *Aorta and infrarenal vena cava referenced.* ***B)*** *Identification of the inferior mesenteric vein.*

and referred with silk for subsequent portal perfusion *(Figure 4B)*.

It is preferred not to cannulate at this time to avoid accidentally decannulating the great vessels during the rest of the dissection.

d. **Hepatic Dissection.** A compress is placed on the inferior border of the left lobe, and electrocautery is used on the left triangular and coronary ligaments to free the left lobe *(Figure 5A)*.

Dissection of the lesser moment or gastrohepatic ligament continues, taking care to preserve any accessory hepatic artery or left replacement arising from the stomal coronary artery. It should be preserved if present, procuring the celiac trunk *(Figure 5B and C)*.

Subsequently, the structures of the hepatic hilum are dissected. The Dissection of the common bile duct begins at the right lateral border, taking care not to devascularize the pericoledochal vessels, which are located at 3 and 9 o'clock in the circumference of the biliary tract. It is distally ligated with silk at the level of the duodenum and sectioned *(Figure 5D)*.

The vesicular fundus is incised and irrigated with an aseptic syringe until a clear solution emerges through the sectioned biliary tract. It is essential to remember that the right hepatic accessory or replacements pass in the inferior border of the common bile duct, which must be preserved from its inflow at the level of the superior mesenteric artery previously dissected. It is easy to identify them by palpation through Winslow's hiatus at the beginning of the dissection *(Figure 5E)*.

Subsequently, dissect the neuro-lymphatic tissue at the left border of the hilum to dissect the hepatic artery proper only a few millimeters from the gastroduodenal artery. Continue with proximal dissection of the hepatic artery proper to the celiac trunk. This latter dissection can be performed more easily once clamped and cold *(Figures 5F and G)*.

We proceed to dissect the portal vein, which is located below both the biliary tract and the hepatic artery, freeing the neuro-lymphatic tissue until its emergence at the level of the pancreas so that after perfusion, it is designed intrapancreatic, cutting a few millimeters below the affluence of the superior mesenteric vein with the splenic vein *(Figure 5H)*.

Liver dissection is complete.

e. **Hepatic cannulation and *precooling*.** Before the anesthesiologist administers 35,000 IU of IV heparin, blood samples are taken from the vena cava and lymph nodes for histocompatibility testing. The aorta is ligated above the bifurcation of the iliac arteries and proximally cannulated for retrograde Perfusion *(Figure 6A)*.

   Subsequently, the inferior mesenteric vein and cannula are tied distally for portal perfusion with venoclisis equipment; in this phase, hepatic precooling begins with slow drip infusion of the preservation solution *(Figure 6B)*.

f. **Dissection of the supraceliac aorta and diaphragmatic incision.** The last Dissection before cold Perfusion consists of dissecting the supraceliac aorta below the diaphragm. The right diaphragmatic pillar is incised to locate the supraceliac aorta and refer with umbilical tape. The right diaphragm is incised to open the thoracic cavity and extends medially to the pericardium exposing the heart *(Figure 7)*.

g. **Perfusion.** It is essential to note the time of clamping. The vascular *clamp* is ligated or placed in the supraceliac aorta, the aortic and portal preservation solution infusion systems are entirely opened, the right atrium is sectioned, and two aspirators are placed in the thoracic cavity for exsanguination and installation of sterile ice completely covering both kidneys and liver. An average of four liters of preservation solution is infused per aorta and two liters per portal system. *In situ* cold Perfusion of the organs lasts approximately 20 minutes *(Figure 8)*.

h. **Explant.** For hepatic procurement, start by sectioning the inferior vena cava above the inflow of both renal veins and the aorta at the level of the superior mesenteric artery, taking care not to injure the emergence of the renal arteries and the great vessels are detached from the dorsal plane *(Figure 9A)*.

   The dissection of the hepatic hilum continues, sectioning the portal vein at

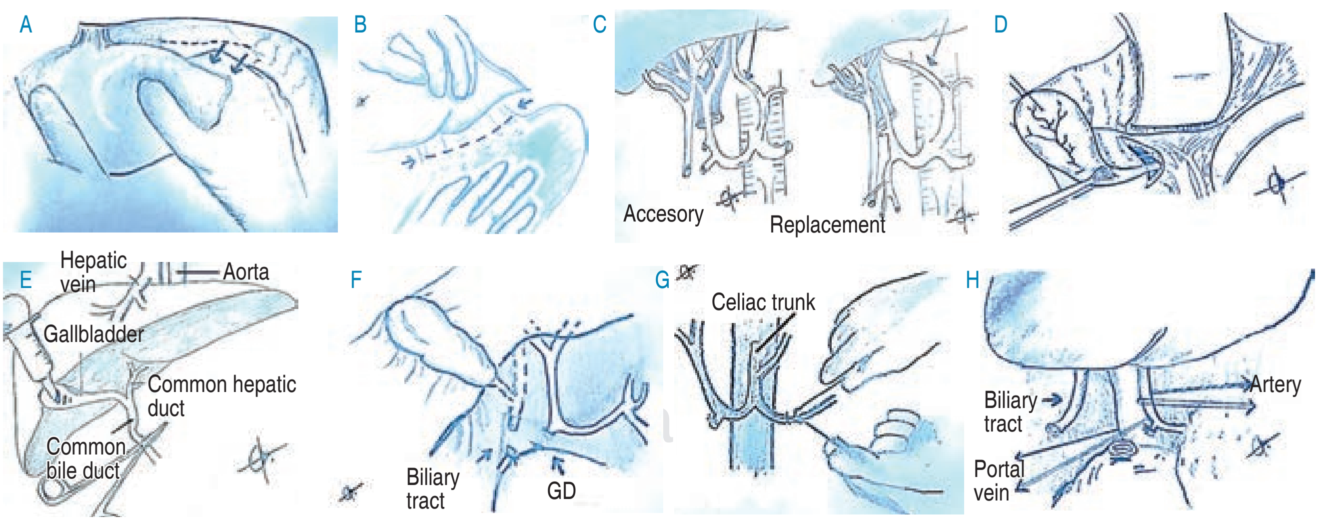

***Figure 5:* A)** *Incision of the left triangular and coronary ligament.* **B)** *Incision of the lesser omentum.* **C)** *Accessory or left replacement.* **D)** *Dissection of the biliary tract.* **E)** *Lavage of the biliary tract.* **F)** *Direction of the hepatic artery.* **G)** *Celiac trunk dissection.* **H)** *Portal dissection.*

GD = gastroduodenal.

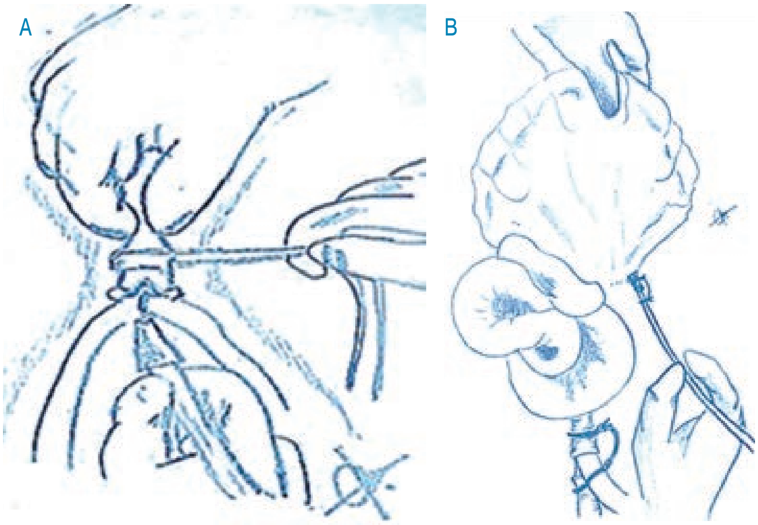

Figure 6: A) *Aortic cannulation.* ***B)*** *Inferior mesenteric vein cannulation.*

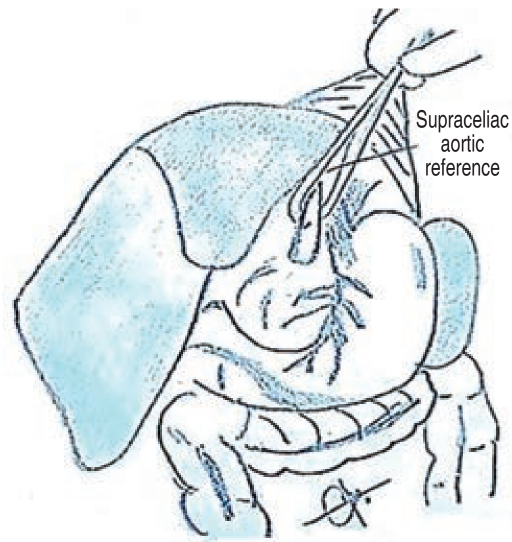

Figure 7: *Supraceliac aorta referenced.*

the described level. The gastroduodenal artery is sectioned, and the hepatic artery itself is dissected up to the celiac trunk, cutting the splenic and left gastric artery (in case it does not have any accessory artery or left replacement if it does, it must be preserved) to section the aorta at the level of the clamp. The aorta or an aortic patch around the ostium of the celiac trunk, including the superior mesenteric artery (in case of any accessory artery or right replacement), should be removed *(Figure 9B)*.

The index finger is then introduced through the retrohepatic vena cava at the pericardial level. The diaphragm that includes it is sectioned, cutting the right diaphragm together with the ipsilateral triangular and coronary ligaments. The liver is now freely removed from the abdomen and placed in the ice-filled container for review at the bench surgery.

The kidneys are explanted *en bloc* to minimize the risk of vascular injury. The ureters are cut at the level of the iliac junction, the inferior vena cava at the level of the iliac inflow, and the aorta at the level of the cannulation. The bowel is retracted anteriorly and superiorly. The left transmesocolic window is opened to dislocate the left kidney to the inframesocolic space *(Figure 9C)*.

Ureters, renal poles, and great vessels are lifted, and a section of the paravertebral muscles is initiated. Both kidneys are obtained and placed on the back table in an ice container.

Finally, the common, hypogastric, and external iliac arteries and veins are procured for packing with the liver *(Figure 9D)*.

Packaging

Another 1.5 liters of preservation solution is infused per portal vein, 500 cm^3 per hepatic

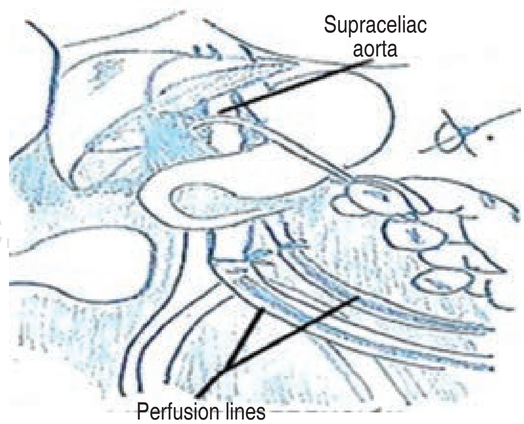

Figure 8: *Supraceliac impingement.*

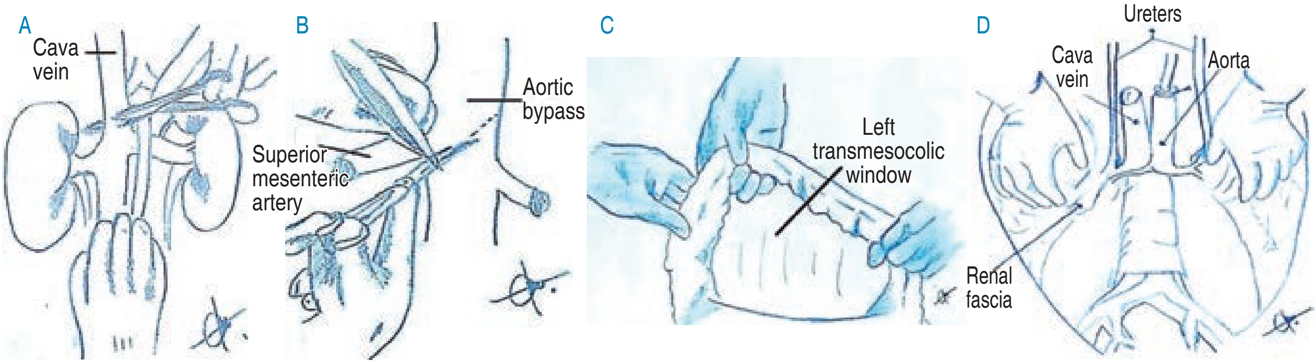

Figure 9:* A) *Cut of suprarenal cava vein.* B) *Cut off the aortic patch.* C) *Transmesenteric window.* D) *Renal block explant.

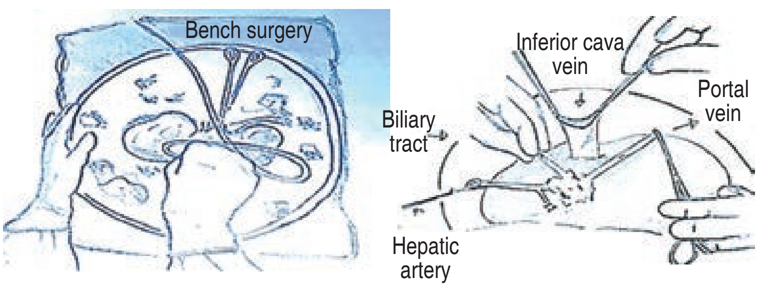

Figure 10: *Renal and hepatic perfusion and packing.*

artery, and packing is performed with the organ submerged in this solution with three sterile protective bags. The kidneys are separated, sectioning the left renal vein in its affluence with the cava to preserve the latter with the left renal vein for its use if elongation is required. The anterior side of the aorta is cleaned, and an incision is made along its midline, allowing the equivalent patch on each side of the renal artery and its polar. Infuse with 500 cm^3 of preservation solution per renal artery and perform packing similarly to the liver *(Figures 10 and 11)*.

DISCUSSION

Let us begin the discussion by contextualizing a pandemic with epidemiological figures with a disputed underreporting in our country. Mexico continues to be on the list of countries with high transmissibility for SARS-CoV-2.[10]

In addition, most of first- and second-level hospitals (donor centers) and third-level and high-specialty hospitals (transplant centers) had to convert into COVID units, severely affecting transplant activity throughout the country.

This effect was not only observed in Mexico. Most transplant centers worldwide have reduced the number of procedures due to the pandemic. At the end of March 2020, a survey of 88 US transplant institutions reported that 71% had suspended living donor kidney transplantation altogether, and 84% had implemented restrictions on deceased

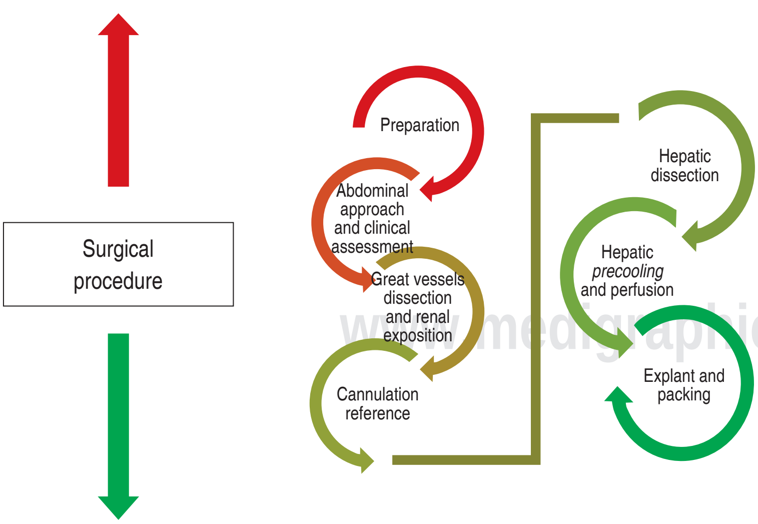

Figure 11: *Algorithm for surgical aspects.*

donor kidney transplantation.[11] Another report reported productivity reductions of 51% and 90% in solid organ transplantation procedures in the US and France.[12]

The impact on the decrease in multi-organ donations in Spain was most affected during the March-May period, coinciding with the worst months of the pandemic; however, according to reports from the ONT, these have recovered to levels approaching those recorded in 2019.[13] This recovery is staggered, contrary to what has been observed in Mexico, where so far activity is minimal.

All this may correspond to emerging countries are very different from the first world. Marcelo Cantarovich and collaborators mention several points to consider before performing any deceased donor organ transplantation in developing countries: limitations in personal protective equipment, high prevalence of asymptomatic infections, availability of RT-PCR tests, isolation rooms, and intensive care unit beds, duplication of functions in health care workers, the changing dynamics of this pandemic and finally the overload on the existing health care system. Each unit must study case-by-case, weighing the feasibility of performing procurement and transplantation versus the resources available to manage the pandemic.[14]

Although the potential for SARS-CoV-2 transmission through transplantation is unknown, there are already multiple international reports on the transplanted population. Domínguez-Gil et al. published 363 cases of COVID-19 in organ transplant patients four months after the pandemic in Spain, where most were community-acquired with a median time of 56 months after transplantation. Only 62 (14%) cases of nosocomial infections were reported, in no case with suspected donor-derived infection.[15]

Case series published in the US with more than 400 solid organ transplant recipients have provided information on the clinical presentation of COVID-19 in this population, yielding a mortality of 6-30%.[16] Pereira and his group reported a series of 90 solid organ transplant recipients with COVID-19 with the following symptoms: fever (70%), cough (59%), and dyspnea (43%); 76% required hospitalization and 35% mechanical ventilation. Overall mortality was 18%.[17] In Mexico, CENATRA reports overall mortality of 25% of confirmed and suspected cases as of December.[18]

In order to continue the attention to these priority programs, trying to reduce the health risk of SARS-CoV-2 infection, both in Mexico and internationally, multiple recommendations were issued that coincide with each other for the evaluation and selection of organ donors and recipients in the current context.[19]

One of these recommendations is the performance of RT-PCR and thorax tomography to all potential donors, which is why we analyze in this article the feasibility and the time it added to the procurement process in our environment, being this of 12 extra hours, which did not put the donation event at risk. Clarifying that this surgery was performed in a High Specialty Unit with the capacity to run the polymerase chain reaction in its laboratory, a reality uncommon in most procuring hospitals in the country. The reactivation of our donation program was based on five fundamental guidelines:

1. Assess resources for screening potential donors.
2. Availability of resources in intensive care and shock areas.
3. Risk/benefit assessment of subjecting an immunocompromised patient to the risk of SARS-CoV-2 infection vs. the risk of mortality by remaining on the waiting list.[20]
4. Ability to transfer organs and tissues out of state.
5. Procurement by local surgical teams.

In our country, multi-organ procurement will always be urgent, so it is imperative to resume near-normal activities as soon as possible.[7,8] A strict evaluation of the potential donor before organ procurement will continue to be the cornerstone of the transplant process and an excellent surgical technique, even in the COVID-19 contingency.

Finally, Communication between donation and transplantation teams in the country is critical to minimize ischemia time and achieve a good result for organ transplantation. It should be taken into account that any anatomical variation may occur during transplantation; therefore, extreme care should be taken to avoid damage to vessels and organs that may endanger the transplantation.

CONCLUSION

The development of organ donation and transplantation has been extraordinarily complex but feasible, as shown in the present case. The most significant impact, we believe, is not in the procurement but in the implantation due to the saturation situation and the lack of COVID-19-free areas in the hospitals, which guarantees the safety of the transplanted patient.

Although it is too early to assess the impact on mortality rates associated with this decline in donation and transplantation activity, it is presumable that deaths on waiting lists that would have been avoidable under normal circumstances will increase.

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Ethical considerations and responsibility: data privacy. Following the protocols established in our work center, it is declared that the protocols on patient data privacy have been followed, preserving their anonymity.

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