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CLINICAL AND SURGICAL FACTORS RELATED TO OUTCOME IN PATIENTS WITH SUBDURAL HEMATOMA: ¿IS PNEUMOCEPHALUS A PREDICTOR FACTOR OF RECURRENCE AND MORTALITY? PNEUMOCEPHALUS AS AN OUTCOME FACTOR

TESIS

QUE PARA OBTENER EL TITULO DE ESPECIALISTA EN

NEUROCIRUGÍA

PRESENTA

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TOLUCA, ESTADO DE MÉXICO, MARZO 2023

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207C040101020015/JIC/171/2022
Metepec, México; 09 de junio de 2022

DR. ARTURO MIGUEL ROSALES AMAYA
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PRESENTE

Con relación a su trabajo de investigación ***"Clinical and surgical factors related to outcome in patientes with subdural hematoma: ¿is pneuencephalus a predictor factor of mortality and recurrence?",*** con número de registro UEeIM 059/22, se le informa que fue evaluado y ***aprobado*** por los Comités de Ética en Investigación e Investigación en Salud en su sesión ordinaria número 240, celebrada el 09 de junio de 2022.

Sin más por el momento, reciba cordiales saludos

ATENTAMENTE

DR. ALBERTO DOMÍNGUEZ CADENA
SECRETARIO DE LOS COMITÉS

c.c.p. expediente

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1. ABSTRACT

OBJECTIVE: Identify the factors related to the outcome of patients with subdural hematoma taking into consideration the presence of pneumocephalus.

MATERIALS AND METHODS: This retrospective observational study consists of a case series of patients admitted with a diagnosis of SDH in the period from March 2018 to February 2021. When necessary, qualitative variables were described by absolute frequencies and percentages and compared using the chi-square test or Fisher's exact test. Statistical significance was defined as a two-tailed $p < 0.05$.

RESULTS: 44 (48.9%) patients presented pneumocephalus, with a statistically significant difference in age with an average age in the group with postoperative pneumocephalus of 69.5 years (+ 13.6) vs. 59.1 (+20.1) in the no - pneumocephalus group. 80% of the patients in whom irrigation was not performed presented pneumocephalus, vs. 42.1% of those patients in whom this maneuver was performed.

CONCLUSIONS: performing subdural irrigation with saline solution during the transoperative period significantly reduces the presence of pneumocephalus in the postoperative period. Pneumocephalus was not a factor in the development of added neurological deterioration.

Keywords: Subdural hematoma, pneumocephalus, postoperative pneumocephalus, subdural hematoma surgery

RESUMEN

OBJETIVO: Identificar los factores relacionados con la evolución de los pacientes con hematoma subdural teniendo en cuenta la presencia de neumocéfalo.

MATERIALES Y MÉTODOS: Este estudio consiste en una serie de casos de pacientes ingresados con diagnóstico de hematoma subdural en el periodo comprendido entre marzo de 2018 y febrero de 2021. Las variables cualitativas se describieron mediante frecuencias absolutas y porcentajes y se compararon mediante la prueba de chi-cuadrado o el test exacto de Fisher cuando fue necesario. La significación estadística se definió como una p de dos colas < 0,05.

RESULTADOS: 44 (48,9%) pacientes que presentaron neumocéfalo, con una diferencia estadísticamente significativa en cuanto a la edad, con una edad media en el grupo con neumocéfalo postoperatoria de 69,5 años (+ 13,6) frente a 59,1 (+ 20,1) en el grupo sin neumocéfalo. El 80% de los pacientes en los que no se realizó la irrigación presentaron neumocéfalo, frente al 42,1% de los pacientes en los que se realizó esta maniobra.

CONCLUSIONES: la realización de la irrigación subdural con suero fisiológico durante el período transoperatorio reduce significativamente la presencia de neumocéfalo en el postoperatorio. El neumocéfalo no fue un factor para el desarrollo de deterioro neurológico añadido.

Palabras clave: Hematoma subdural, Neumocéfalo, Neumocéfalo postoperatorio, Cirugía de hematoma subdural

2. INTRODUCTION

Subdural hematoma (SDH) is a blood collection that forms in the virtual space between the meningeal layers of the dura mater and the arachnoid. The bleeding comes from the bridge veins that drain blood flow from the central nervous system to the venous sinuses of the dura mater. Acute subdural hematoma (ASDH) causes intracranial hypertension that requires urgent surgical management. Chronic subdural hematoma (CSDH) is caused by bleeding in the subdural space, which is generally not symptomatic at first and progresses to a collection due to a chronic inflammatory process over> 3 weeks. Symptoms range from behavioral changes, and focal neurological deficits to seizures, headache, and hemiparesis **(1).**
Morbidity in ASDH ranges from 35-80% present with a Glasgow Coma Scale (GCS) score of 8 or less. A talk and deterioration have been described in 6% of patients with a GCS score of 3-15. Mortality in patients with ASDH with GCS score of 3-15 has ranged from approximately 30-60% **(2),** and prognostic factors associated with a poor prognosis are 1) coexisting intracranial lesions, including cerebral hemorrhage and generalized edema; 2) changes in cerebral blood flow (CBF), 3) coagulopathy, 4) late clinical deterioration, and 5) use of prehospital antiplatelet and oral anticoagulants.

For CSDH morbidity is estimated at 0-25%, and mortality at 0-32%; factors associated with poor prognosis are: 1) advanced age; 2) obesity; 3) lower GCS score or poor clinical status at initial patient assessment; and 4) presence of comorbidities such as kidney failure, liver cirrhosis, and coagulopathy **(3).**

It is called pneumatocele, pneumocephalus, or aerocele to the presence of air in the intracranial compartment; it can be extra-axial (epidural, subdural, subarachnoid) or intraaxial (parenchymal, intra-ventricular, intra-vascular). It is more commonly found after trauma or surgery, rarely associated with infections and tumors, and can be fatal if not treated properly **(5).** This entity was described since the 19th century and documented in multiple cases spanning the beginning of the 20th century with Dandy who in 1926 documented 25 cases in a literature review and added 3 more from his clinical practice **(4).** It is one of the most frequent findings after surgical management of patients with subdural hematoma, although its clinical-surgical relevance has not yet been well-studied.

Ishiwata et al. described the image produced by the pneumocephalus in subdural collections that separate both frontal lobes as a Mount Fuji sign, in appearance similar to the silhouette of the famous Fuji Volcano in Japan. When the presence of pneumocephalus produces increased intracranial pressure that leads to neurological deterioration it is known as tension pneumocephalus and surgical evacuation is usually indicated. **(6.7)**

In this study, the focus was given to the different factors involved in the morbidity and mortality of patients suffering from a subdural hematoma in any of its variants, taking into consideration postoperative pneumocephalus, a factor not properly reviewed in previous studies, so we include it as a possible factor of deterioration in a patient with combined risk factors, as it is often considered a complication.

3. PROBLEM STATEMENT

Due to the limited literature on the complications of pneumocephalus secondary to subdural hematoma drainage surgery (SDH) and its relationship with morbidity and mortality in patients with this pathology, there is little evidence on which we can base to avoid this condition, as well as the frequency of occurrence according to the chronicity of subdural hematomas.

4. RESEARCH QUESTION

Is pneumocephalus a predictor factor of recurrence and mortality?

5. OBJECTIVES

To demonstrate whether postoperative pneumocephalus is a predictor of recurrence and mortality and to identify the preferred technique to avoid pneumocephalus secondary to subdural hematoma drainage.

6. RATIONALE

There is little literature and evidence on the maneuvers and techniques to avoid pneumocephalus in the transoperative period, perhaps because of the little transcendence and deleterious effect they usually produce. It is important to have, in an objective manner, the factors that favor the formation of tension pneumocephalus and how to avoid them in the transoperative period. Previous studies have shown that the presence of pneumocephalus in 226 patients concluded that the presence of postoperative pneumocephalus in drainage of subdural hematoma by trephine correlated with higher recurrences of hematoma, as well as higher frequency of secondary epileptic seizures. **(8)**

7. MATERIAL AND METHODS

7.1. Research design.

Observational, prospective, and longitudinal

7.2. Patients

This study consists of a case series of patients admitted to the Neurosurgery service with a diagnosis of SDH in the period from March 2018 to February 2021 at the Toluca Medical ISSEMyM. The inclusion criteria were: 1) Age over 18 years, 2) Diagnosis of SDH by simple computed tomography of the skull (CT), and 3) patients in whom surgical management was decided in the ISSEMyM Neurosurgery service. The exclusion criteria were: 1) previous surgical management of SDH; 2) patients lost to outpatient follow-up; 3) patients who died of causes not associated with subdural hematoma. A review of the clinical charts of this center was carried out, from which the demographic data, surgical results, imaging, and evolution during the hospital stay and follow-up by outpatient consultation were taken. The present study was approved by the ethics and research committee of the institution (ISSEMyM_2020_000 Folio UEeIM 059/22).

7.3. Clinical and Radiological Evaluation

Clinical evaluation was performed using the Glasgow Coma Scale (GCS) **(9)** on admission and 24 hours postoperatively. The final clinical outcome was evaluated with the modified Rankin scale (mRS) **(10).** The radiological evaluation was performed through a simple helical computed axial tomography (CAT) scan, with 1.25mm cuts (General Electric's equipment model Brivo CT385). The diagnostic criteria for subdural hematoma by CT were the following: 1) Acute subdural hematoma: extra-axial, hyperdense lesion (approximately 50-90 HU) **(11)** with a crescent shape (2). 2) Subacute subdural hematoma (SASDH): isodense extra-axial lesion (approximately 30-40 HU) **(11, 12)** concerning the brain parenchyma, 3) Chronic subdural hematoma (CSDH): low-density extra-axial lesion (approximately 15-22 HU) **(11)** and 4) Chronic subdural hematoma with acute hemorrhage (CASDH) when the CSDH had areas of hyperdensity**.** The Marshall Classification System (MCS) **(12)** and the Rotterdam Computed Tomography Score (RCTS) **(13 - 16)** scoring systems were used for radiological classification of the associated brain injuries.

Postoperative control CT was performed, and the following factors were evaluated: 1) adequate drainage of the hematoma; 2) absence of immediate complications of the surgical event; 3) presence and degree of pneumocephalus. Tension pneumocephalus was defined as 1) the presence of air within the subdural space with Mount Fuji image associated with 2) neurological deterioration not justified by another pathological condition of the patient; 3) the absence of other intracranial postoperative complications by CT **(17).**

7.4. Surgical Technique

The surgical approaches were divided as follows: 1) single trephine; 2) unilateral multiple burrs; 3) bilateral burr holes, 4) craniotomy, and 5) craniectomy. The indications for each technique were based on the consideration and experience of the neurosurgeon in charge of the procedure.

Patients were placed in a supine position with head rotation contralateral to the injury. The incision was centered on the planning site of the trephine(s); in the case of craniotomy, a linear or centered horseshoe incision was made. In the case of craniectomy, a question mark incision was made. The procedures were performed with high-speed drilling equipment (MidasRex® IPC Model EC 300) and the dura mater was incised, allowing controlled exit of the hematoma while it was irrigated with saline solution. Membranes and septa, if present, were removed and coagulated. Subsequently, subdural drainage with a silicone reservoir with a capacity of 250ml directed towards the rostral direction (catheter of 14Fr and 30cm long) was left, exteriorized through a counter-opening **(18, 19).** In the case of performing irrigation, (which was decided by the surgeon in charge and considering potential candidates to prevent pneumocephalus) and subdural lavage after the drainage procedure and 1L of 0.9% physiological solution was used; seeking 1) continue the constant washing of the space to eliminate any remaining clot in spaces not visible to the neurosurgeon and 2) keep the subdural space free from air entry by the continuous flow of solution. For the solution to pass, a subdural catheter was used, without connection of the reservoir bag, instead connecting the 90 ml syringe, which was kept constantly filled with the solution so that it would not be completely emptied, thus having continuous irrigation; all this was developed by a third helper. The syringe was always kept above the level of the head with a continuous flow while the dura mater was closed. At the end of the closure, the catheter is clamped with hemostatic forceps. At the end of the complete skin flap closure, the subdural drainage system is opened, leaving it at the level of the head, allowing it to drain towards the reservoir.

7.5. Statistical Analysis

Continuous variables were expressed as mean and standard deviation (SD) or median and interquartile range (IQR) and were compared using the Student's T test or the Mann–Whitney U test according to the Kolmogorov–Smirnov test of normality. Qualitative variables were described by absolute frequencies and percentages and were compared using the chi-square test or Fisher's exact test when necessary. The presence of interaction and the role of confounding factors were evaluated. Statistical significance was defined as a two-tailed $p < 0.05$. The analysis was performed using SPSS, version 21.0 (SPSS, Inc., Chicago, IL, USA).

7.6. Variables

Variable name	**Operational definition**	**Measurement instrument**	**Value unit**	**Values or categories**	**Scale of measure ment**
Age	Time passed in years since birth until the moment of surgery	Medical file	Years	≥18 years.	Interval
Gender	Social concepts of the roles, behaviors, activities, and attributes that each society considers appropriate for men and women.	Medical file	Categoric	Female Male	Nominal.
Burr hole	Surgical trephine made for the evacuation of intracranial blood or craniotomy initiation	Medical file	Categoric	Yes No	Nominal
Craniotomy	A surgical procedure in which a bone flap is removed for exposure of intracranial structures	Medical file	Categoric	Yes No	Nominal
Rankin	Scale to measure the patient's outcome	Medical file	Categoric	Grades 1-6	Ordinal
Glasgow Coma Scale	Scale to measure the patient's neurologic status at the first evaluation	Medical file	Categoric	3-15	Ordinal
Subdural hematoma	Presence of blood in the intracranial space	Computed tomography scan	Categoric	Acute Sub-acute	Ordinal

	between the dura mater and arachnoid membrane			Chronic	
Surgical approaches	Type of surgical procedure made for the evacuation of the subdural hematoma	Medical file	Categoric	-Single Burr hole - Unilateral multiple burr holes -Bilateral burr hole -Craniotomy -Craniectomy	Nominal
Subdural irrigation	Surgical technique in which saline solution is used to eliminate clotting, blood, and air through a catheter in the subdural space.	Medical file	Categoric	Yes No	Nominal
Pneumocephalus	Presence of air in the intracranial space between the dura mater and arachnoid membrane	Computed tomography scan	Categoric	Yes No	Nominal
Recurrence	Presence of subdural bleeding in a time-lapse of >30 days after previous surgical drainage of the SDH	Computed tomography scan	Categoric	Yes No	Nominal
Disease	The death of the patient corroborated with disease certificate	Death certificate from the medical file	Categoric	Yes No	Nominal

8. RESULTS

8.1. Epidemiological Data

During the period between March 2018 and February 2021, 224 patients were evaluated with head-brain trauma and 90 were diagnosed with SDH. A mean follow-up of 6 months was given. The average age was 64 years, with 25.6% women. The patients presented an average glycemia at hospital admission of 129.4mg/dl, and they reported the following comorbidities: 1) without comorbidities, 30%; 2) type 2 diabetes mellitus (DM2), 11.1%; 3) systemic arterial hypertension (SAH), 20%; 4) one patient (1.1%) had kidney disease, 5) 25.6% had DM2 and SAH concomitantly, and 6) 12.2% patients were found to have another pathology. Of the 90 patients in the cohort, 75 (83.3%) had a unilateral and 15 (16.7%) bilateral SDH. Regarding the chronicity of the SDH, the following were found: 1) 28 (31.1%) with ASDH; 2) 19 (21.1%) SASDH; 3) 30 (33.3%) CSDH; and 4) 13 patients with CASDH. By skull CT, it was found that the patients presented findings according to the Marshall scale of I) 0 patients; II) 22 (24.4%); III) 9 (10%); IV) 39 (43.3%); V) 5 (5.6%); and VI) 15 (16.7%) of the patients. In addition, an average of 3.1 was found according to the Rotterdam classification **(Table 1).**

		n=90	
	Mean (IQ) age (years)	64 (47-81)	
	Gender Female Male	23 (25.6%) 67 (74.4%)	
	Chronicity of SDH Acute Sub-Acute Chronic Chronic with acute bleeding	28 (31.1%) 19 (21.1%) 30 (33.3%) 13 (14.4%)	
	Glasgow Coma Scale (SD) At Emergency arrival After craniectomy	11.7 (3.4) 14.1 (0.6)	**p= >0.0001**
	SDH location (%)	Unilateral Bilateral	75 (83.3) 15 (16.7)
	CT on arrival		
	Marshall (%)	I II III IV V VI	0 22 (24.4) 9 (10) 39 (43.3) 5 (5.6) 15 (16.7)
	Rotterdam (SD)	3.1 (1.07)	
	Comorbidities (%)	No Comorbidities DMII Systemic Hypertension Renal Insufficiency > 1 Comorbidity Others	27 (30) 10 (11.1) 18 (20) 1 (1.1) 23 (25.6) 11 (12.2)
Outcomes			
	Hospital stay (SD)	6.4 days (8.3)	
	Surgical procedure (%)	No Surgery Craniotomy Sole trephine Multiple unilateral trephines Bilateral trephines	9 (10) 37 (41.1) 15 (16.7) 11 (12.2) 10 (10.1)
	Postoperative pneumocephalus	44 (48.9)	
	Reoperation	8 (8.9)	
	Rankin outcome scale (%)	I II III IV V VI	37 (41.1) 9 (10) 10 (11.1) 10 (11.1) 3 (3.3) 21 (23.3)

Table I. Baseline characteristics of patients and outcomes *Baseline characteristics of patients* **IQ**, interquartile; **SDH**, subdural hematoma; **SD**, standard deviation; **CT**, Computed Tomography.

8.2. Clinical and Surgical Outcome

The surgical procedures performed were: 1) 37 (41.1%) Craniotomy; 2) 10 (11.1%) due to bilateral trephines; 3) 15 (16.7%) per single trephine; 4) 11 (12.2%) multiple trephines ipsilateral to the lesion and 5) 8 patients (8.9%) thorough craniectomy. Of the total number of patients (n=90), 9 (10%) did not undergo surgical treatment. During the procedure, subdural saline irrigation was performed in 57 patients (70.3%). The average time of the procedures was 144.8 minutes (± 63.5).

At post-surgery CT, pneumocephalus was found in 44 patients (48.9%). The average length of hospital stay was 6.4 days (+ 8.3). Postoperative complications occurred in 12.3% of patients: 1) recurrence of SDH in 8 (8.9%); and 2) surgical site infection in 2 patients (2.2%). The mortality rate was 23.3% (21 patients). The final clinical outcome was evaluated at the last follow-up consultation recorded in the file with the modified Rankin scale (mRS): I) 37 (41.1%); II) 9 (10%); III) 10 (11.1%); IV) 10 (11.1%); V) 3 (3.3%); VI) 21 (23.3%) of the patients.

8.3. Factors Associated with the Presence of Post-Operative Pneumocephalus (Figure 1)

There was a total of 44 (48.9%) patients who presented pneumocephalus, with a statistically significant difference in age with an average age in the group with postoperative pneumocephalus of 69.5 years (+ 13.6) vs. 59.1 (+20.1) in the no - pneumocephalus group. In the group of patients without pneumocephalus, there was also a statistically significant difference concerning the Rotterdam score in the preoperative CT, with a Rotterdam of 2.9 in patients with pneumocephalus, vs. 3.3 in patients without postoperative pneumocephalus. Patients with bilateral SDH (92.8%) presented a statistically significantly higher incidence of pneumocephalus than those with unilateral SDH (41.8%). Regarding the chronicity of the subdural hematoma, the greater the chronicity, the greater the incidence of postoperative pneumocephalus, with 40.9% of patients with CSDH and 22.7% with CASDH vs. 13.6% of patients with ASDH. The use of irrigation with saline solution, according to the technique described in the methodology, represented a statistically significant protective factor for developing postoperative pneumocephalus, since 80% of the patients in whom irrigation was not performed presented pneumocephalus, vs. 42.1% of those patients in whom this maneuver was performed. The type of surgical procedure, on the other hand, did not represent a statistically significant factor for the development of postoperative pneumocephalus. The presence of postoperative pneumocephalus did not represent a statistically significant factor for recurrence and re-operation of patients due to SDH **(Figure 2),** nor for the final clinical outcome according to the mRS (Figure 4); on the other hand, patients with postoperative pneumocephalus presented a lower mortality rate (26.3%) compared to patients without postoperative pneumocephalus (56.5%), with a statistically significant difference. No patient fulfilled the criteria for tension pneumocephalus.

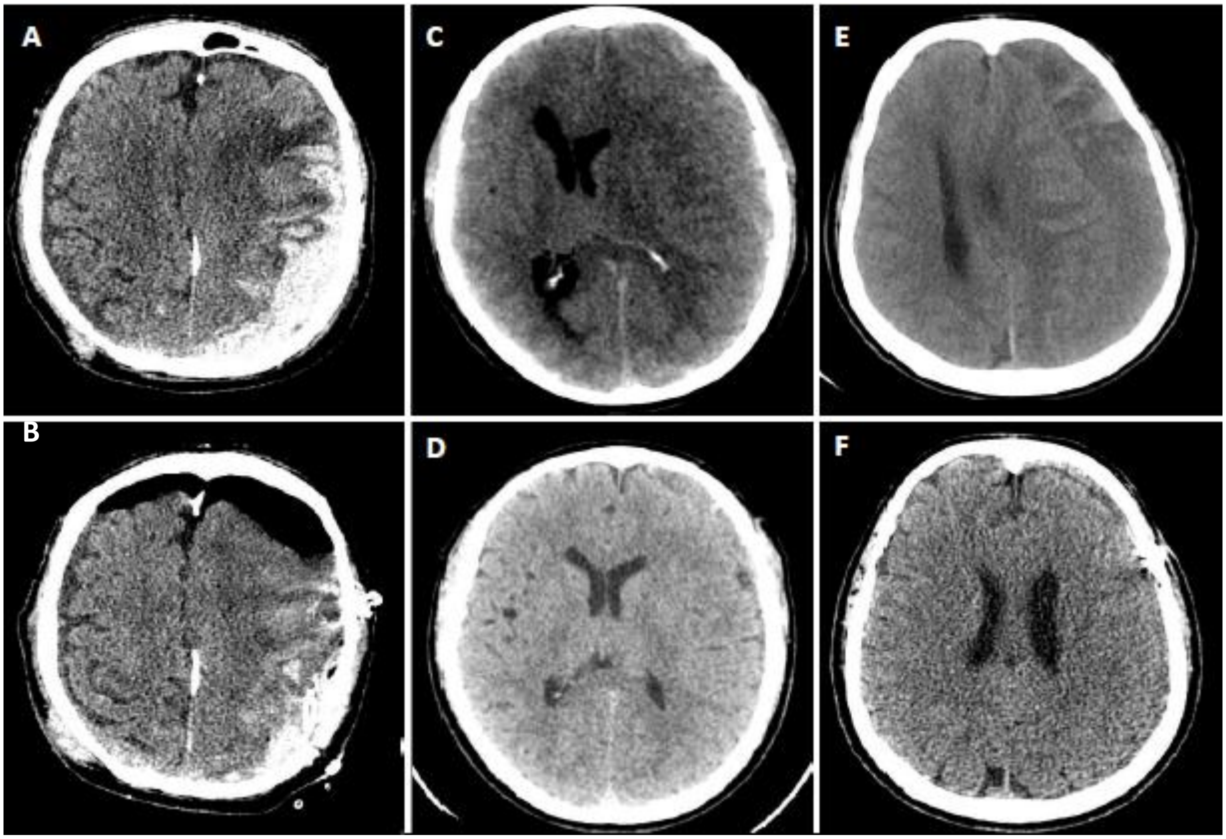

Figure 1. Preoperative (A) and postoperative (B) CT of a patient with an acute subdural hematoma. Presence of postoperative pneumocephalus; no irrigation was used during the procedure, and the Mount Fuji sign is seen in the postoperative CT. Preoperative (C) and postoperative (D) CT of a patient with a subacute subdural hematoma. No pneumocephalus was present using saline irrigation in this case. Preoperative (E) and postoperative (F) CT of a patient with chronic subdural hematoma; irrigation was used in this case and no pneumocephalus was seen in the postoperative CT.

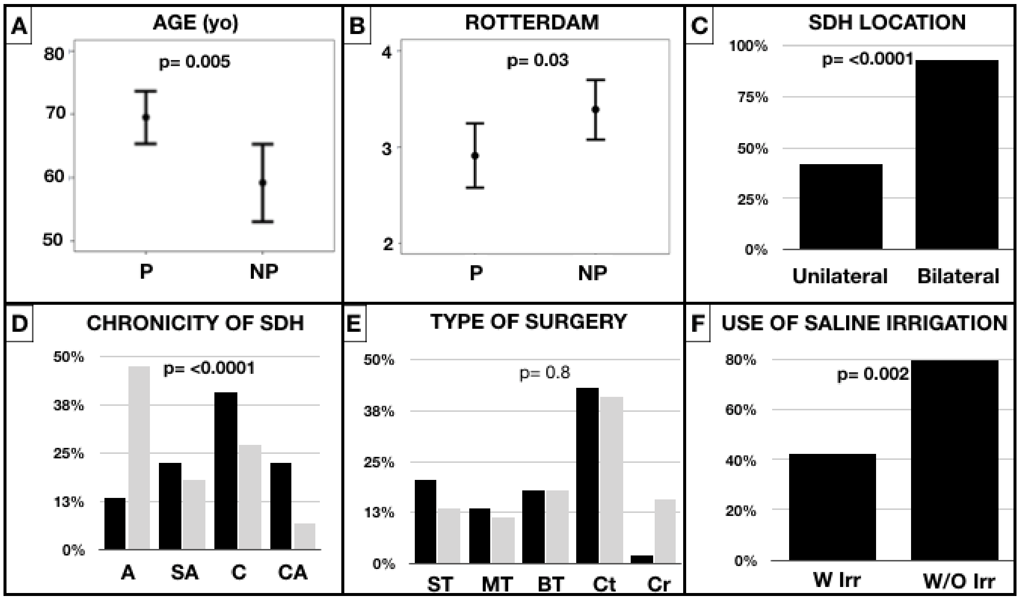

Figure 2. Factors related to postoperative pneumocephalus. [A] Bar-error charts showing the presence or absence of postoperative pneumocephalus by age, and [B] by preoperative Rotterdam CT Scoring; [C] Bar charts showing the percentage of patients with postoperative pneumocephalus depending on subdural hematoma location. [D] Bar charts with the percentage of patients with (black bar) and without (gray bar) postoperative pneumocephalus depending on the chronicity of subdural hematoma, and [E] type of surgery performed for SDH evacuation. [F] Bar chart showing the percentage of patients with postoperative pneumocephalus depending on the use of subdural space irrigation with saline solution. ***yo**, years old; **P**, Presence of pneumocephalus; **NP**, absence of pneumocephalus; **SDH**, Subdural hematoma; **A**, Acute; **SA**, Subacute; **C**, Chronic; **CA**, Chronic with acute hemorrhage; **ST**, sole trephine; **MT**, Multiple trephines; **BT**, Bilateral trephines; **Ct**, craniotomy; **Cr**, Craniectomy; **W Irr**, with irrigation; **W/O Irr**, without irrigation.*

8.4. Factors Associated with Recurrence / Reoperation (Figure 2)

In the present study, we found that the factor related to recurrence with a statistically significant difference was the chronicity of SDH, with patients diagnosed with CSDH having a higher recurrence rate (23.3%). We found no statistically significant relationship between age, location of the SDH, the presence of postoperative pneumocephalus, the type of procedure performed, or the use of saline irrigation for the incidence of recurrence and the need for reoperation for SDH.

8.5. Factors Associated with Final Clinical outcome and Mortality (Figures 3- 6)

There was a statistically significant difference in hospital admission due to glycemia for final clinical status and mortality, with both patients with mRS $\geq$ 3 (142.9mg/dl) and patients who died during follow-up having a higher admission glycemia (154.2mg/dl). /dl), compared to those with mRS $\leq$ 2 (115.6mg/dl) and patients who survived until the end of the study (121.7mg/dl), **(Figures 3C and 5C)**. Similarly, the longer duration of the surgical procedure was related to an mRS $\geq$ 3 (153.6 minutes) and higher mortality (174 minutes), compared to patients with mRS $\leq$ 2 (101.2 minutes) and with survival at the end of the study (113.8 minutes), **(Figures 3B and 5B)**. The chronicity of SDH, the type of surgery, and the Marshall scale in the preoperative CT was statistically significantly related to the clinical outcome and mortality, with a higher percentage of patients with Rankin $\geq$ 3 and a higher mortality rate in patients with SDHa, those submitted to craniectomy and craniotomy, and Marshall $\geq$ IV **(Figures 4 and 6).** Hospital stay was related to clinical outcome, with patients with mRS $\geq$ 3 having an average hospital stay of 9 days, vs. patients with mRS $\leq$ 2, 3.9 days. The presence of pneumocephalus was statistically significantly related to lower mortality. We found no statistically significant difference regarding the mRS and the mortality rate with age, comorbidities, gender, location of the SDH, and Rotterdam staging in preoperative CT.

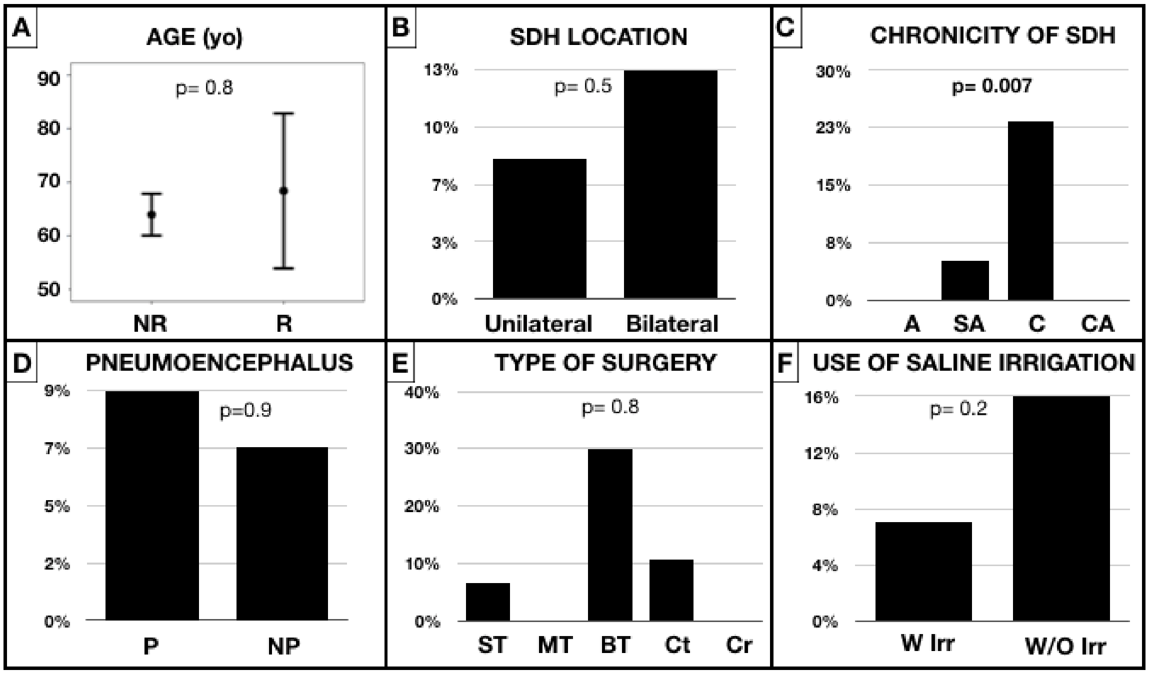

Figure 3. Factors related to reoperation. [A] Bar-error charts with patients with Non-recurrence vs. Recurrence of SDH by age [B] Bar charts with the percentage of patients with recurrence depending on SDH location; [C] Bar charts with the percentage of patients with recurrence depending on the chronicity of subdural hematoma; [D] Bar charts with the percentage of patients with recurrence of SDH depending on the presence or absence of postoperative pneumocephalus; [E] Bar chart with the percentage of patients with recurrence of SDH depending on the type of surgery performed for SDH evacuation. [F] Bar chart showing the percentage of patients with recurrence of SDH depending on the use of subdural space irrigation with saline solution. ***NR****, Non-recurrence;* ***R****, Recurrence;* ***P****, Presence of pneumocephalus;* ***NP****, absence of pneumocephalus;* ***SDH****, Subdural hematoma;* ***A****, Acute;* ***SA****, Subacute;* ***C****, Chronic;* ***CA****, Chronic with acute hemorrhage;* ***ST****, sole trephine;* ***MT****,*

Multiple trephines; ***BT****, Bilateral trephines;* ***Ct****, craniotomy;* ***Cr****, Craniectomy;* ***W Irr****, with irrigation;* ***W/O Irr****, without irrigation.*

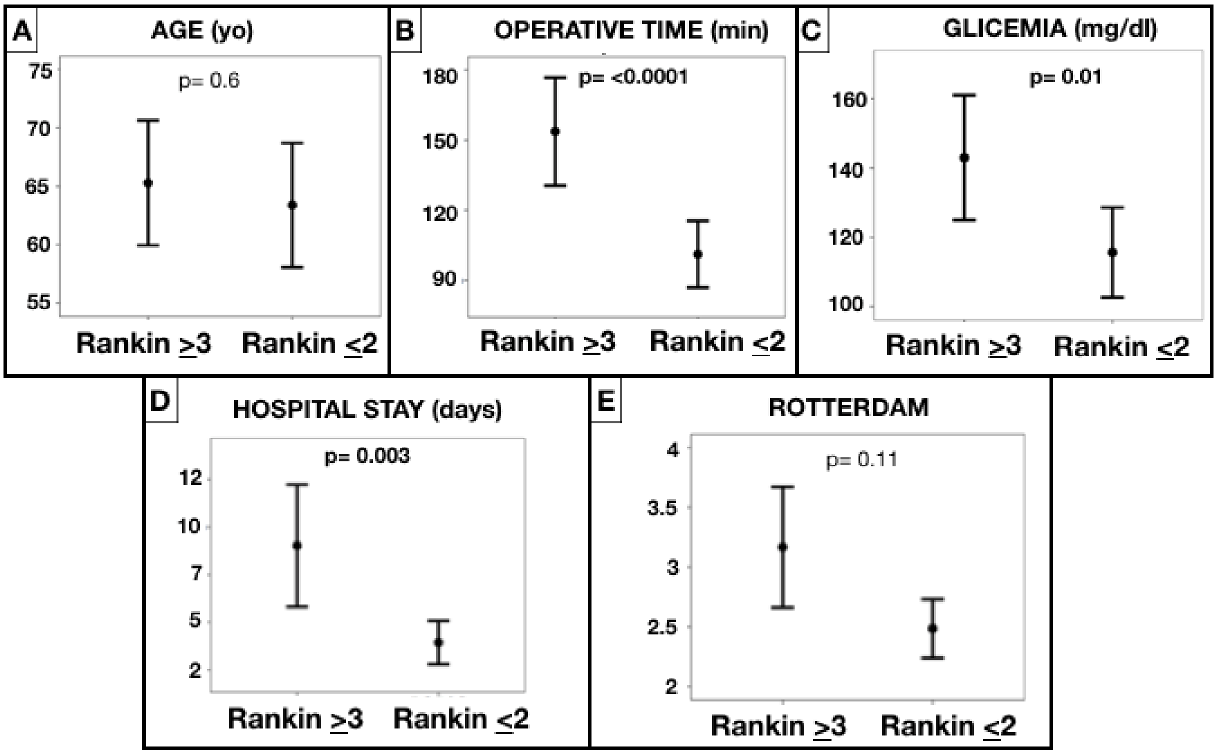

Figure 4. Bar error charts of Factors related to Outcome (modified Rankin scale). [A] Age; [B] Operative time; [C] Glycemia at hospital admission; [D] Days of hospitalization; [E] Preoperative Rotterdam scoring on CT. ***yo****, years old;* ***min****, minutes.*

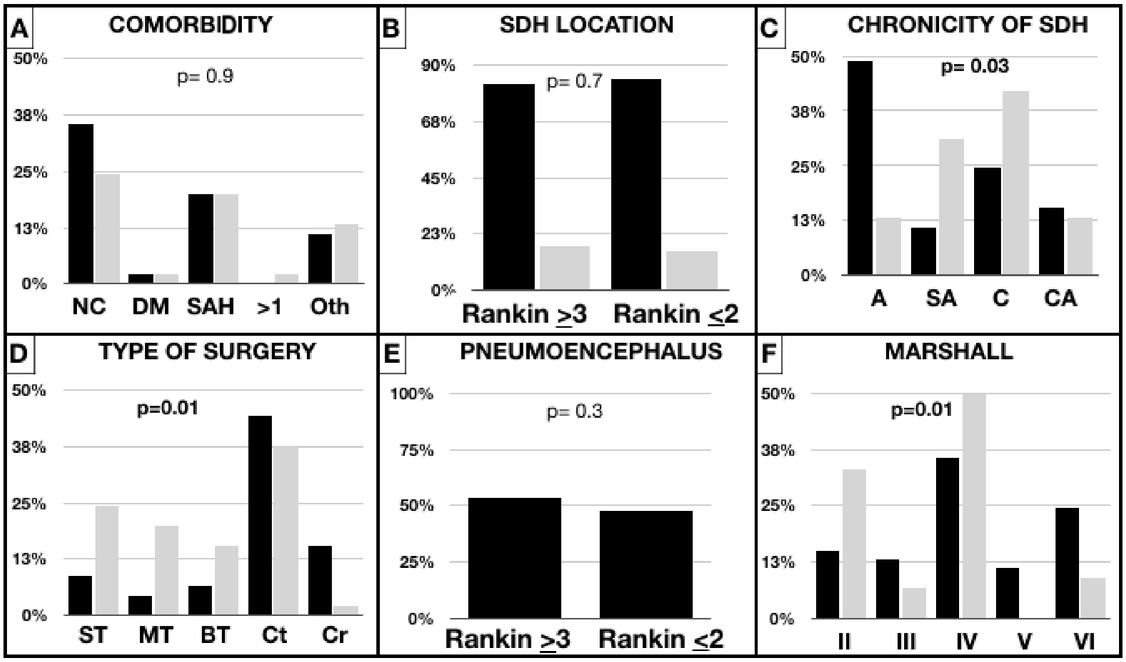

Figure 5. Factors related to Outcome. [A] Bar chart of patients with modified Rankin Scale (mRS) > 3 (black bars) and mRS < 2 (gray bars) related to comorbidities [B] Bar charts with the percentage of patients with unilateral (black bars) vs. bilateral (gray bars) of subdural hematoma location related to clinical outcome; [C] Bar charts with the percentage of patients with mRS > 3 (black bars) and mRS < 2 (gray bars) depending on the chronicity of the SDH; [D] Bar charts with the percentage of patients with mRS > 3 (black bars) and mRS < 2 (gray bars) related to the surgical procedure performed; [E] Bar chart with the percentage of patients with pneumocephalus related to clinical outcome. [F] Bar chart showing the percentage of patients with mRS > 3 (black bars) and mRS < 2 (gray bars) related to the Marshall scale on preoperative CT. ***NC****, no comorbidity;* ***DM****, Diabetes Mellitus type 2;* ***SAH****, systemic arterial hypertension;* ***>1****, more than 1 comorbidity;* ***Oth****, others comorbidities;* ***SDH****, Subdural hematoma;* ***A****, Acute;* ***SA****, Subacute;* ***C****, Chronic;* ***CA****, Chronic with acute hemorrhage;* ***ST****, sole trephine;* ***MT****, Multiple trephines;* ***BT****, Bilateral trephines;* ***Ct****, craniotomy;* ***Cr****, Craniectomy.*

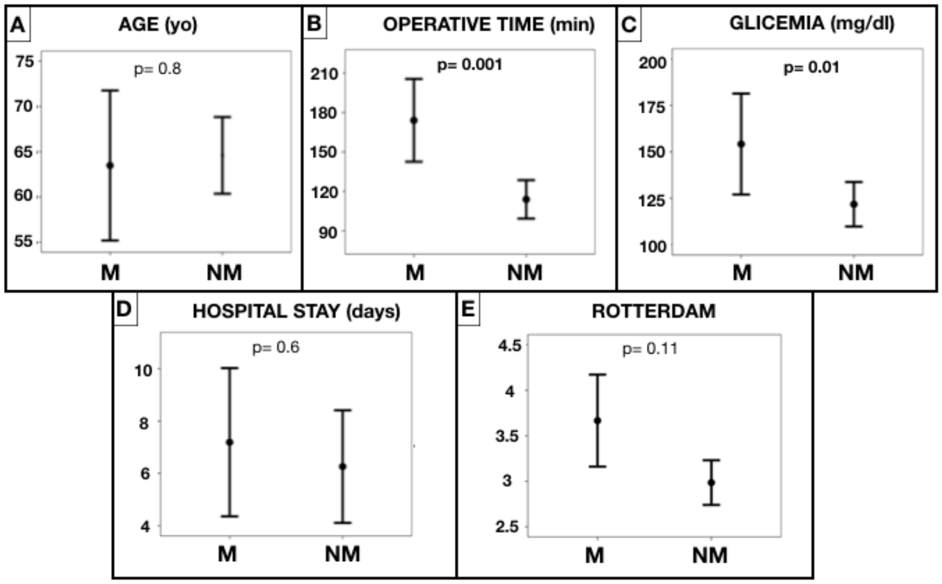

Figure 6. Factors related to Mortality. [A] Age; [B] Operative time; [C] Glycemia at hospital admission; [D] Days of hospitalization; [E] Preoperative Rotterdam scoring on CT. ***yo****, years old;* ***min****, minutes;* ***M****, Mortality;* ***NM****, No Mortality.*

9. DISCUSSION

The subdural space is a virtual space in which the dura mater is separated from the arachnoid by a thin layer of marginal cells. Which contains flat, elongated cells connected by desmosomes with amorphous extracellular matrix and limited extracellular fibers. This structure allows this cellular layer to be a natural anchoring plane in which the dura mater easily separates from the arachnoid. During craniotomy and dural opening, the meninges' most common plane of separation is between the marginal cell layers. Evidence that CSDH forms in the dural marginal cell layer include electron microscopic studies showing marginal cells in the inner and outer membrane of CSDH. In addition, the walls of the veins traversing from the cortex to the dura are thinnest where they traverse the dural layer of marginal cells.

The annual incidence of CSDH is 1-5.3 cases per 100,000 individuals. Risk factors include chronic alcoholism, long-term anticoagulation (e.g., aspirin, heparin, warfarin), and therapeutic interventions (e.g., ventricular shunts), all of which lead to fluctuations in intracranial pressure and traction on the intracranial vasculature **(1,18)** and the surgical technique of choice for the treatment of CSDH continues to be a topic of debate **(18,19).**

In the case of ASDH, they are usually complicated by coexisting intracranial injuries, including a variety of diffuse injuries, blunt hematomas, and edema. Furthermore, it is also modified by subsequent phenomena such as 1) changes in cerebral blood flow (CBF), 2) coagulopathy, 3) late deterioration, and 4) pre-hospital oral antiplatelet and anticoagulant agents **(2).**

One post-surgical imaging finding that generates anxiety in the surgical team regarding the possibility of morbidity or re-operation is pneumocephalus. There is little literature and evidence, from 1980 to date, about the maneuvers and techniques to avoid pneumocephalus in the intraoperative period despite the deleterious effect that it can produce, such as symptoms, from headache, dizziness, and seizures, to mental status disorders**. (20).** In this study, a retrospective analysis of patients diagnosed with subdural hematoma in any of its presentations who underwent surgical treatment was performed, registering those patients who developed postoperative pneumocephalus and those who did not. According to the results of the study, a tendency was seen not to present postoperative pneumocephalus in patients who underwent subdural irrigation during closure compared to those who developed pneumocephalus despite irrigation, being statistically significant. It is important to note the fact that the success of the irrigation technique is largely dependent on the neurosurgeon performing the procedure; considering that the simple act of not achieving an adequate elimination of air in the subdural drainage system could predispose the formation of more pneumocephalus in the patient. Another fact is how the selection of the use of irrigation or not was carried out, and it was completely dependent on the neurosurgeon to perform the procedure that could influence the results.

Taking into consideration what was previously mentioned, we were able to show that patients subjected to burr holes, whether single or bilateral, presented pneumocephalus more frequently compared to craniotomies. This can be compared to other old reports of pneumocephalus, such as the case of 1983 and 1984 in which a case report of 3 patients was published by Hasegawa H **(22)** and that of K Suda and M Sato **(23)** of a patient, a 71-year-old man who underwent drainage of a bilateral subdural hematoma through trephines, which was carried out without incident, and 5 days after surgery, the patient presented rapid neurological deterioration with altered consciousness. The presence of a tension pneumocephalus was confirmed, requiring drainage through a new burr hole. This was not the case in our study since the patients with pneumocephalus did not present neurological deterioration attributable to it, during the postoperative period. In the case of ASDH, the presence of pneumocephalus was less, probably because, being an acute head injury, it is very frequently accompanied by cerebral edema, not allowing the presence of air as an added intracranial component. A fact that calls our attention, obtained from this study, is that the presence of postoperative pneumocephalus was a statistically significant factor for lower mortality. It is probably related to the greater presence of pneumocephalus in patients with a less severe or urgent context such as CSDH, in which patients are relatively more stable and present, for the most part, lower intracranial pressure and cerebral atrophy due to their age in which we find this type of pathology.

Another important surgical point in the management of subdural hematomas is the possibility of recurrence. According to what was previously published, we also found that the chronicity of SDH was the most important factor since patients with CSDH presented bleeding recurrence more frequently compared to the other types of SDH. In our study, age, location of the SDH, the presence of postoperative pneumocephalus, the type of procedure performed, or the use of irrigation with a saline solution was not statistically significant in the recurrence of the hematoma; compared to studies such as the one by Opšenák René et al **(26)** in which they observed that the incidence of recurrence was slightly higher in patients undergoing hematoma drainage through trephination, but we agree with the study by Haron et al **(27)** in which no significant difference was seen in both, and it should be noted that they did show significance in the presence of diabetes mellitus as a risk factor for recurrence compared to our study in which it was not favored. Although there is evidence that the use of antiaggregants, such as aspirin, is a factor for the development of a subdural hematoma with a relative risk (RR) of 1.5 as reported in a meta-analysis **(24),** it has not shown statistical significance in others such as the one developed by PC Poon et al in which they compare the use of anticoagulants and antiaggregants in the rate of recurrence, concluding that the risk of developing vaso-occlusive diseases is only increased by withdrawing these drugs for surgical intervention **(25)**; in the present study, this information was not available to be able to report it.

The clinical outcome and mortality in our study were unfavorably affected in patients with ASDH, mainly since they are patients in the context of acute head trauma with a GCS <8 at the initial assessment, and the presence of comorbidities at the time of hospital admission, such as hyperglycemia, which was statistically significant with mRS >2 and mortality.

Performing craniotomy vs. craniectomy did not show a significant difference between the two, compared to the study by Kevin Phan et al. **(28)** in which higher mortality and morbidity were seen in patients undergoing decompressive craniectomy. In other studies, this factor has a variable and inconsistent influence. Hatashita et al. **(29)** reported several factors that influence the mortality of ASDH, coinciding with our study, in which patients with shorter surgical time were favored in survival, showing mRS > 3 and higher mortality in times greater than 2 hours and a half on average.

10. CONCLUSIONS

In our series, the presence of pneumocephalus was not a factor for the development of added neurological deterioration, as it did not occur in any of our patients. The chronicity of the hematoma was another important factor for the development of pneumocephalus, being higher in CSDH compared to the other types of subdural hematomas. Another important fact to highlight is that performing subdural irrigation with saline solution during the transoperative period significantly reduces the presence of pneumocephalus in the postoperative period, being statistically significant. The factors associated with poor functional and survival prognosis were the neurological status at admission (GCS), findings related to greater severity of trauma by imaging (Rotterdam and Marshall), high glycemia on admission, longer surgical time, and presence of ASDH. We also want to mention, more studies will need to be made for the analysis of the individual subdural hematoma variations, correlating pneumocephalus with other risk factors in patient outcomes.

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