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Ultrasound identification of the cricothyroid membrane. Systematic review and meta-analysis Detección de membrana cricotiroidea con ultrasonido.

Detección de membrana cricotiroidea con ultrasonido. Revisión sistemática y metaanálisis

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What do we know about this problem?

Palpation of the cricoid membrane is a recommended technique to assess patient airway; however, it may fail. Ultrasonography has been suggested as a superior intervention for its correct identification.

What new contributions does this study make?

This study suggests – with low certainty of the evidence – that ultrasound is superior as compared to palpation for the detection of the CTM, according to clinical trials and observational studies. This association is still present in sensitivity analyses, excluding studies with a high risk of bias, cadaver studies and settings other than the operating room.

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Abstract

Introduction: The no-ventilation no-oxygenation situation is extremely important due to its high mortality. In these cases, open cricothyroidotomy is indicated. Around fifty percent of the difficulties are the result of inadequate identification of the cricothyroid membrane (CTM).

Objective: To determine whether ultrasonography is superior to palpation to identify the CTM at the first attempt.

Methods: A systematic review and a meta-analysis were conducted on the identification of the cricothyroid membrane versus palpation in Medline/Central and Embase. Clinical controlled trials and observational studies were included. Two authors independently and in duplicate selected the studies, assessed the biases and extracted the data; a random effects meta-analysis was successfully conducted for the correct identification of the CTM. The risk of bias was assessed and the certainty of the evidence was qualified. CRD42021223961.

Results: 464 studies were included of which 15 met the eligibility criteria; 6 were clinical trials y 9 were observational. Ultrasound is superior to palpation in the detection of the CTM (RR 1.88, 95 % Cl 1.05-3.36) according to the clinical trials, and it was also superior in observational studies (RR 1.76, 95 % Cl 1.36-2.28). The association was preserved in the sensitivity analyses.

Conclusions: Ultrasonography is superior to palpation for the correct identification of the TCM, though the certainty of the evidence is low. Further studies with better methodology are needed to improve both certainty and precision.

Keywords: Airway management; Ultrasound; Cricoid membrane; Systematic review; Meta-analysis; Anesthesiology.

Resumen

Introducción: La situación de no ventilación-no oxigenación es de gran importancia dada su elevada mortalidad. En dichos casos, la cricotiroidotomía abierta está indicada. Cerca de la mitad de las dificultades son causadas por inadecuada identificación de la membrana cricotiroidea (MCT.

Objetivo: Determinar si la ultrasonografía es superior a la palpación para identificar la MCT al primer intento.

Métodos: Se realizó una revisión sistemática y metaanálisis de identificación de membrana cricotiroidea versus palpación en Medline/Central y Embase. Se incluyeron ensayos clínicos controlados y estudios observacionales. Dos autores de manera independiente y por duplicado realizaron la selección de estudios, la evaluación de sesgos y la extracción de datos, se efectuó un metaanálisis de efectos aleatorios con el éxito de identifica-ción correcta de la MCT. Se evaluó el riesgo de sesgos y se calificó la certeza de la evidencia. CRD42021223961.

Resultados: Se incluyeron 464 estudios de los cuales 15 cumplieron criterios de elegibilidad, 6 fueron ensayos clínicos y 9 observacionales. La eco-grafía es superior a la palpación para detección de la MCT (RR 1,88, IC 95 % 1,05-3,36) según los ensayos clínicos y, similarmente, fue superior para los estudios observacionales (RR 1,76, IC 95 % 1,36-2,28); la asociación se conservó en los análisis de sensibilidad.

Conclusiones: La ultrasonografía es superior a la palpación para detectar correctamente la MCT, aunque con baja certeza de la evidencia. Se re-quieren más estudios con mejor calidad metodológica para mejorar la certeza y la precisión.

Palabras clave: Manejo de vía aérea; Ultrasonido; Membrana cricotiroidea; Revisión sistemática; Metaanálisis; Anestesiología.

INTRODUCTION

Echography represents a highly versatile, safe, non-invasive, free of ionizing radiation, economic and increasingly available tool which may be practically used in any hospital setting. (1)

Its value has been widely recognized over the past few years under the term POCUS (point of care ultrasound), based on its convenience to make specific assessments in a short period of time with the purpose of answering precise questions for timely decision-making. With this scheme, the windows assessed are limited, which allows for both ability and reproducibility of the observations (1), hence contributing to making ultrasound a tool to support the advanced management of the airway and the identification of a successful intubation. (2)

The unanticipated difficult airway is a scenario with a high risk for morbidity and mortality and thus its prediction has been widely studied. However, it has been challenging to identify high performing clinical tools, in part due to a still incomplete understanding of the mechanisms involved in a difficult airway, the low incidence of this scenario, the morphological variability according to the population studied, the inconsistency of the assessment by different reviewers, and the limited discriminative ability of the predictors; all of these may account for this situation. (3)

Over the last few years, a large number of studies have shown that some ultrasound measurements may improve the forecast of the difficult airway (4.5); however, there is no consensus about which are the most appropriate measurements. The "no ventilation – no oxygenation" scenario is one of the most pressing occurrences in the airway because of the high risk of mortality.

Under these circumstances, emergency open cricothyroidotomy is indicated; nevertheless, in a closed review of claims it has been described that half of the difficult open cricothyroidotomy attempts could be explained by an inadequate identification of the cricothyroid membrane. (6) Considering that ultrasonography could improve the percentage identification of the cricothyroid membrane, a systematic review and a meta-analysis have been suggested to respond to this uncertainty.

OBJECTIVE

To establish whether bedside ultrasonography is superior to palpation in adult and pediatric patients, to identify the cricothyroid membrane at the first attempt.

METHODS

This study adhered to the PRISMA-P (7) recommendations for the development of the protocol and PRISMA for the abstract report; since the protocol referred to a secondary study, it was not submitted to the ethics committee; however, it was registered under code CRD42021223961, prior to the systematic search in the PROSPERO platform.

Primary outcome

The adequate proportion of CTM identification by group. The gold standard to confirm the cricothyroid membrane defined previously was the identification by an expert radiologist or anesthesiologist, with proven experience in ultrasonography

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and/or computed tomography (CT) or magnetic resonance imaging (MRI).

Planned secondary outcomes

Detection time, degree of ease of the technique, learning curve of each technique, operator satisfaction, adverse events.

Eligibility criteria

Controlled clinical trials, quasiexperimental trials, and diagnostic studies with interventions to identify the CTM using ultrasonography by any health practitioner - regardless of the technique or type of probe, in populations of any age, under any clinical setting: education, emergency department, hospitalization, critical and surgery, were included. The outcome was the identification of the CTM by a radiologist or expert personnel, whether using ultrasound or by any other means. Clinical simulation studies were excluded.

Sources of information

The following databases were reviewed: Medline via PubMed, Embase and Central, in addition to a grey literature search.

Search strategy

An external advisor who is a professional librarian, designed a comprehensive and specific search strategy (Complementary material 1).

Selection process

The titles of the articles found as a result of the searches were filtered to remove duplicates. The selection of eligible articles was carried out in two phases, independently and in duplicate, by two of the authors and an external collaborator.

Phase one

Two authors searched all the titles and abstracts to exclude the studies that were not relevant for the review. If no abstract was found, but the study title was suggestive of eligibility, the full article was searched.

Phase two

After all the potentially eligible titles and abstracts were selected, they were reviewed by the two authors independently and chosen according to the eligibility criteria. Differences were resolved by a third investigator.

Data collection process and data list

Data were extracted from the eligible studies by the two investigators independently and in duplicate, according to the designed format. The data list included date, author, population, patient inclusion criteria, exclusion criteria, number of participants, diagnostic criteria used, reference standard used, comparator, confounder control, and observations. This format was reviewed after the first three articles for possible modifications; in case of differences between the two authors, the third author resolved the disagreement. Relevant data not found in the article were requested from the corresponding author by e-mail or through the funding institution.

Risk of bias of individual studies

The assessment of risk of bias of the clinical trial-type studies was conducted using the ROB 2 tool. This is a risk of bias tool reviewed

and recommended by the Cochrane collaboration of assessing random trials. It consists of fixed domains on the main types of biases in these studies and a decisionmaking algorithm on the degree of risk to be rated. (8) For the observational studies, the ROBINS tool (9) was used separately, independently and in duplicate; it was then taken to consensus by the three authors.

Effect measurements

Considering that the outcome assessed is the proportion of adequate identification of MCT, the measure of effect chosen for the meta-analysis was the relative risk with a confidence interval of 95 %.

Synthesis methods

The analysis was planned separating observational studies from clinical trials. After fulfilling assumptions for synthesis including clinical diversity, a quantitative synthesis based on the inverse variance method was proposed, with a random effects model, summarized in a forest plot, the calculation of heterogeneity was performed with the l2 statistic.

Metabias analysis report

If more than 10 studies were found, statistical analysis of publication bias was performed using Egger's test; otherwise, only a funnel plot was used.

Sensitivity and subgroup analysis

A sensitivity analysis by risk of bias was considered and a subgroup analysis by potential effect-modifier variables was planned according to the protocol: the age range, type of operator, type of transducer, setting where the procedure was performed, and the subgroup of patients classified with difficult airway.

Other analyses

Calculation of the aggregate Z-value in a trial sequential analysis (TSA) and the total sample value needed to find differences was performed to identify whether a larger sample size would be required.

Assessment of the certainty of the evidence

It was performed using the GRADE strategy, as recommended by the Cochrane manual for evidence synthesis of interventions. It was planned for each outcome, in the case of clinical trials assuming high certainty and then decreasing the assessment according to five dimensions: risk of bias, inconsistency, indirect evidence, imprecision and publication bias, independent and in duplicate, by means of the GRADEPRO direct access program (10).

Figure 1. Flowchart of studies included.

The quantitative synthesis, sensitivity analyses and meta-analyses were performed with the Meta package of the R 1.4 statistical software; the calculation of the TSA was performed with the TSA software of the University of Copenhagen (11), both of which are free.

RESULTS

Selection of the studies

The systematic search found 62 specific articles and 362 from other sources. After eliminating duplicates, 362 articles were found, of which 32 passed phase 1 screening by title and abstract, 15 studies were included for narrative synthesis (12-26), of which 6 were controlled clinical trials and 9 observational studies, that were included in the quantitative synthesis. The flow chart of the individual studies is shown in Figure 1.

With regards to the characteristics of the studies included, it should be highlighted that 14 were performed in adult patients or bodies, and only one in pediatric patients; general, obstetric and obese population was included. The most common primary outcome was the proportion of adequate CTM identification, the vast majority under control of a trained anesthesiologist, ultrasound specialist or radiologist; the characteristics of the studies are summarized in Table 1.

Bias risk

The individual risk assessment is discriminated for clinical trials in Figure 2, and for observational studies in Figure 3.

QUANTITATIVE SYNTHESIS

In terms of the outcome "adequate CTM identification", in the opinion of the authors there was not a broad clinical diversity. The validation criteria included the type of operators of the techniques, the populations and the MCT identification technique itself, for the studies included that prevented quantitative synthesis. Therefore, quantitative synthesis of RCTs (Figure 4) and observational studies were performed (Figure 5).

Ultrasound is superior to palpation for the identification of the CTM with a RR 1.88 (95 % Cl 1.05; 3.36), risks difference RD of 30 % (95 % Cl 8; 53) according to the clinical trials included with high heterogeneity I2 69 %; this result is consistent for observational studies RR 1.76, (95 % Cl 1.36; 2.28) RD of 38 % (95 % Cl 23; 54) with high heterogeneity I2 94 %.

Not enough information was found for the other suggested outcomes; no adverse events are described and only three studies included the time to identification: Kirskensen (2015) with a mean of 48 seconds SD (20) versus 18 seconds SD (10); Forshaw (2018) with a mean of 35.5 SD (20.69) versus 14.18 SD (7.64) and Barbe (2014) with 27



Source: Authors.

Table 1. Characteristics of the studies.

Study ID and type	Intervention	Control	Number of patients/ tests	Age group	Learning curve	Outcomes	Notes
Kristensen (12) 2015 ECA	Technical longitudinal ultrasonography	Conventional technical palpation	35/35	Adult	Anesthesiologists with a mean experience of 6 years completed a structured training program: an online learning module followed by a 30-minute conference and a 20-minute practical training in live models.	Successful CTM identification. Time to identify the membrane with both techniques.	The interventions were randomized in only one patient
Siddiqui <u>(13)</u> 2015 ECA	Technical longitudinal ultrasonography	Conventional technical palpation	24/23	Adult bodies	10 minute lecture on cricothyroidotomy with the Portex® cricothyroidotomy kit (Smiths Medical, USA), followed by a 3-minute video of the palpation and ultrasound technique to identify anatomical landmarks and the CTM, followed by practical echography training at least five times using the Portex® device in human bodies.	Establish the results of the cricothyroidotomy performed in human bodies with the use of ultrasound guidance, as compared to digital palpation of anatomic landmarks.	Few details of the bodies assessed.
You-Ten (14) 2015 ECA	Technical longitudinal ultrasonography	Conventional technical palpation	56/56	Adult obstetric	Not reported	Successful CTM identification.	No patients with a known neck deformity, neck surgery and/ or radiation were studied.
Forshaw <u>(15)</u> 2018 ECA	Technical non explicit ultrasonography	Conventional technical palpation	10/11	Pediatric	Not reported	Successful CTM identification. Time to identify the membrane with both techniques.	Only one reviewer
Siddiqui (<u>16)</u> 2018 ECA	Technical cross-sectional ultrasonography	Technical palpation of laryngeal hands- hake	114/109	Adult	Not reported	Successful CTM identification.	Included patients with a history of previous surgery, radiation exposure and/or neck mass.
Van Emden (<u>17)</u> 2020 ECA	Technical non explicit ultrasonography	Non explicit te- chnical palpation	60/60	Adult bodies	Each participant received a short training in ultrasound-assisted identification of the CTM.	To decide whether the participating anesthesiologists will judge body F4L as 'adequate' (assessment of suitable for learning) and 'realistic' (assessment of its appearance, sensation and flexibility as compared with a living human being), as a teaching model for localization of the CTM through palpation or ultrasound.	Bodies of donors with known neck anomalies or surgical procedures were excluded.
Aslani <u>(18)</u> 2012 EO	Technical non explicit palpation between obese and non-obese	Cross-sectional and longitudinal technical ultrasonography as a control	56/56	Adults	Not reported	Successful identification of the CTM.	The recommendation is to assess and secure the airway in 40 seconds or less.

Table 1. Characteristics of the studies.

Study ID and type	Intervention	Control	Number of patients/ tests	Age group	Learning curve	Outcomes	Notes
Barbe <u> (19)</u> 2014 EO	Cross-sectional technical ultrasonography	Conventional technical palpation	24/24	Adults	Without a previous anatomic reminder	Successful identification of the CTM. Time to identification of the membrane with both techniques.	At six months, interns obtained better results with ultrasound than through clinical detection.
Lamb <u>(20)</u> 2015 EO	Cross-sectional and longitudinal technical ultrasonography	Conventional technical palpation	186/186	Adults	Not reported	Successful identification of the CTM.	Fail to compare this technique with ultrasound or CT as the gold standard.
Yildiz <u>(21)</u> 2017 EO	Longitudinal technical ultrasonography	Conventional technical palpation	120/120	Adults	Brief surgical anatomy of the airway and ultrasound training to identify the CTM before starting the study	Successful identification of the CTM.	Was only conducted by emergency medical personnel, with the assumption that this is a procedure exclusively of the emergency department.
Betul Basaran (22) 2018 EO	Cross-sectional and longitudinal technical ultrasonography	Conventional technical palpation	80/80	Pediatric	Not reported	Successful identification of the CTM.	The overall success rate (55 %) was higher than the general success rates in previous studies conducted in adult populations.
Oh <u>(23)</u> 2018 EO	Conventional vs. laryngeal handshake technical palpation	Longitudinal and cross-sectional technical ultrasonography as a control	123/123	Adults	Reading of the DAS 2015 laryngeal handshake method and an illustrative video.	Successful identification of the CTM.	Previous training was administered to anesthesia residents and not to ENT residents.
Altun <u>(24)</u> 2019 EO	Ultrasonografía, técnica transversal y longitudinal	Conventional technical palpation	110/110	Adults	20-minute PowerPoint presentation on the anatomy of the airway in US	Successful identification of the CTM.	The US group was previously trained, but it was not the same with the palpation group.
Bowness (25) 2020 EO	Ultrasonografía, técnica transversal y longitudinal	Conventional technical palpation and laryngeal handshake technique	33/66	Adults	Not reported	Successful identification of the CTM and ensuring that it is still in the same place despite the mobilization.	The times for performing the maneuvers are not specified.
Lavelle <u>(26)</u> 2021 EO	Ultrasonografía, técnica transversal y longitudinal	Conventional technical palpation	28/28	Adult obstetric	Training of a minimum of 20 echograms and procedure guidelines	Successful identification of the CTM. Time to identification and perception of how easy was the procedure.	The investigators who administered the intervention were blinded to the standard.

CTM: Cricothyroid membrane ; OS: Observational Study; RCT: Randomized clinical trial. **Source:** Authors.



Figure 2. Risk of individual bias for clinical trials.



0%

25%

Low risk

50%

Some concerns High risk

Bias arising from the randomization process Bias due to deviations from intended interventions Bias due to missing outcome data Bias in measurement of the outcome Bias in selection of the reported result

Overall risk of bias



Source: Authors.

Study

Figure 3. Risk of bias in observational studies.

Risk of bias domains D1 D2 D3 D4 D5 D6 D7 Overall Aslany 2012 + + (-)Barbe 2014 (+(+Lamb 2015 + + (+)(+)+ (+)-0 Yildiz 2016 (+)+ Study (-)Betul Basaran 2018 + (+)(+(+)(+)+ Oh 2018 -+ Altun 2019 -(-)++ + Bowness 2020 Lavelle 2021 Domains: D1: Bias due to confounding Judgement Serious D2: Bias due to selection of participants. D3: Bias in classification of interventions. D4: Bias due to deviations from intended interventions. D5: Bias due to missing data. Moderate Lo D6: Bias in measurement of outcomes D7: Bias in selection of the reported result.

> 0% 75% 100% Low risk Moderate risk Serious risk

Metabias report

75%

100

It was not possible to conduct the Egger test due to the small number of studies included; however, a separate plot assessment of the publication bias was performed. The funnel diagram of Complementary material 2 does not give any evidence of publication bias.

seconds SD (5) versus 19.5 SD (7.25) for ultrasound and palpation, respectively.

Sensitivity analysis

A sensitivity analysis was conducted excluding the studies with high risk of bias and another one excluding the studies in cadavers or in the emergency department setting. (Complementary material 2). The relative risk for the correct identification of the cricothyroid membrane at first attempt was maintained.

Subgroup analysis

The analyses planned in the protocol were not conducted because a sufficient description of the effect-modifying variables was missing.

Certainty of the evidence

Following the assessment using the GRADE tool, the certainty of the evidence found was considered to be low, due to the risk of bias and inaccuracy (Figure 6).

A post hoc sequential analysis of the trials (TSA) was conducted, with conventional analysis in random effects and two-tailed α of 0.05, resulting in an accumulated Z value of -2.02, which favors the intervention; it was also evidenced that the sample needed to identify any differences is of 570 patients, hence confirming the strength of the result (Complementary material 2).



Figure 4. Forest plot of clinical trials.

	Experim	nental	Co	ontrol		Risk Rat	tio		Risk R
Study	Events	Total	Events	Total	Weight	IV, Random,	95% CI	IV	, Random
Kirskensen 2015	29	35	13	35	16.5%	2.23 [1.41;	3.52]		
Siddiqui 2015	15	24	9	23	15.4%	1.60 [0.88;	2.90]		
You-Ten 2015	42	56	31	56	17.7%	1.35 [1.02;	1.79]		-
Forshaw 2018	8	10	10	11	17.2%	0.88 [0.61;	1.26]		
Siddiqui 2018	92	114	9	109	15.1%	9.77 [5.19;	8.39]		
Van Emden 2020	55	60	42	60	18.1%	1.31 [1.09;	1.57]		=
Total (95% CI)		299		294	100.0%	1.88 [1.05;	3.36]		-
Heterogeneity: Tau	$^{2} = 0.4792$	2; Chi ²	= 47.24, 0	df = 5 (P < 0.01);	$ ^2 = 89\%$		ſ	I I
								0 1	0 5 4



Favours palpation Favours ultrasound

Source: Authors.

Figure 5. Forest plot of observational studies.

	Experim	nental	Co	Control		Risk Ratio	Risk Ratio			
Study	Events	Total	Events	Total	Weight	IV, Random, 95% C	(I	V, Ranc	lom, 95% (
Aslany 2012	56	56	13	56	9.2%	4.19 [2.63; 6.67]			-	
Barbe 2014	24	24	10	24	9.3%	2.33 [1.48; 3.69]				
Lamb 2015	186	186	79	186	12.4%	2.35 [1.99; 2.77]			. i +	
Yildiz 2016	83	120	80	120	12.3%	1.04 [0.87; 1.23]				
Betul Basaran 2018	80	80	44	80	12.2%	1.81 [1.49; 2.20]				
Oh 2018	123	123	87	123	12.8%	1.41 [1.26; 1.58]				
Altun 2019	82	110	50	110	11.8%	1.64 [1.30; 2.07]				
Bowness 2020	25	33	42	66	11.5%	1.19 [0.91; 1.55]			-	
Lavelle 2021	20	28	11	28	8.6%	1.82 [1.08; 3.05]			-	-
Total (95% CI) Heterogeneity: Tau ² =	0.1332; (760 Chi ² = 7	74.08, df =	793 = 8 (P <	100.0%	1.76 [1.36; 2.28] = 89%	[Ι	-	
							0.2	0.5	1 2	5

Source: Authors.

Figure 6. Table GRADE – summary of findings.



Source: Authors.

DISCUSSION

Ultrasound has revolutionized the medical practice. This study has shown - with low certainty of the evidence - that ultrasound is superior to palpation for the successful identification of the CTM, with a RR of 1.88 (95 % CI 1.05; 3.36) according to the clinical trials included. This result is consistent with the observational studies RR 1.76 (95 % CI 1.36; 2.28). The association was maintained in the sensitivity analyses, excluding studies with high risk of bias and settings outside the operating room, such as cadaveric models. The association was also maintained in the sequential analysis of the trials indicating that the number of observations was adequate in terms of the sample size needed to identify differences between the two interventions.

It should be highlighted that the CTM ultrasound identification protocols included in most cases the longitudinal technique, whereby after identifying the midline, rotates the probe to find the height of the CTM. The majority of the studies include general adult population; one of them included obstetric population and two of them obese population; hence, the application of the results is particularly focused on these populations in an elective surgical environment.

The study herein described found similar results to those of Hung et al. who in a previous meta-analysis of eight studiesincluding clinical and observational studies-, compared ultrasound versus palpation, with a reduction of up to 50 % in the number of failed identifications; RR 0-50 (95 % Cl 0.33; 0.76). (27)

The strength of this study includes the grey literature search which although it didn't add any further studies for the synthesis, it is indeed an indication of the comprehensive nature of the search, the selection, extraction and assessment of biases in an independent manner and in duplicate, in addition to developing the synthesis segregating the clinical trials and the observational studies. The limitations identified in this review include the statistical heterogeneity; however, clinically the authors consider that there is no diversity in the administration of the interventions, and hence it was deemed appropriate for the authors to do a quantitative synthesis for the primary outcome. Another limitation is the small number of studies which increases the inaccuracy of the results. The metaanalysis of observational studies presents a high risk of bias due to imbalanced confounding factors as a result of the lack of randomization and the inclusion of cadaveric studies that may limit the application of the results in clinical practice.

One additional limitation is the clinical diversity of the populations since the interventions were conducted in obstetric, obese and pediatric patients, and in settings outside the operating room; this could favor the external validity of the use of the results, but adds uncertainty to the magnitude of the effect.

With regards to the gaps in the evidence, because of the low certainty of the studies due to risk biases, inaccuracy and statistical heterogeneity, further studies on the superiority of ultrasound versus palpation are needed, in order to strengthen the certainty of the evidence. Another uncertainty is that no primary studies were found on the combination of the ultrasound and palpation techniques, whether sequentially or in parallel.

CONCLUSION

With a low certainty of the evidence, ultrasound is superior to palpation for the correct identification of the CTM. Further studies are needed, with improved quality of the methodology, to strengthen the certainty and the precision of the evidence.

ETHICAL RESPONSIBILITIES

Endorsement by the ethics committee

The study was not submitted to the ethics committee since this was a secondary study.

Protection of humans and animals

The authors declare that no experiments in humans or in animals were conducted for this research. The authors declare that the procedures followed are consistent with the ethical standards of the committee for responsible human experimentation in accordance with the World Medical Association and the Declaration of Helsinki.

Confidentiality of the data

The authors declare that they have followed the protocols of their worksite on the publication of patient data.

Right to privacy and informed consent

The authors declare that no patient data are disclosed in this article. The authors have obtained the informed consent of all patients and/or subjects mentioned in this article. The corresponding author is in possession of this document.

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Contribution of the authors

MAZB. Study planning, collection of data, statistical analysis, interpretation of the results and initial draft of the manuscript. FCB and DPE. Study planning, collection of data, approval of the final draft of the manuscript.

Assistance for the study

No assistance was received for the study.

Financing

The funding was provided by the authors and the Universidad de Antioquia which allowed access to the databases.

Conflicts of interest

The authors declare not to have any conflicts of interest to disclose.

Presentations

A partial result of the study was presented at the Anesthesiology and Resuscitation Section of the School of Medicine of Universidad de Antioquia.

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Availability of the data and complementary Material

The search design is attached in the Complementary material 1; all statistical analyses are shared in Complementary material 2.

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Complementary material 1. Search design.

Desenlace	Pubmed	Embase	Central
Identificación de la	((((echography[MeSH	('echography' /exp	Cricothyroid
membrana	Terms]) OR	OR 'diagnostic	membrane.mp.[mp=
cricotiroidea	(ultrasonography[MeSH	ultrasonic	ti, ot, ab, tx, kw, ct,
	Terms])) AND (cricothyroid	examination' OR 'diag	sh, fx, hw]
	membrane[MeSH Terms]))	nostic ultrasonic	
	OR	imaging' OR 'diagnost	
	((((ultrasonograph*[1itle/Abs	ic ultrasonic	
	tractj) OR	method OR diagnosti	
	(echograph [*] [Ille/Abstract]))		
) AND (CICOUNYIOId mombrane[Title/Abstract])))	aram' OR 'ochographi	
	OR ((Diagnosis/Broad[filter])		
	AND (cricothyroid	evaluation' OR 'echog	
	membrane AND	ranhy' OR 'echoscony	
	ultrasonography))	'OR 'echosound' OR '	
	unideenegraphy //	high resolution	
	Resultados: 53	echography' OR 'scan	
		ning,	
	25/09/20	ultrasonic' OR 'sonog	
	Búsqueda juntando mesh	ram' OR 'sonographic	
	con título/abstract y clinical	examination' OR 'son	
	queries	ographic	
		screening' OR 'sonog	
		raphy' OR 'ultrasonic	
		detection' OR 'ultraso	
		nic	
		evamination' OR 'ultra	
		sonic	
		scanning' OR 'ultraso	
		nic	
		scintillation' OR 'ultra	
		sonogram' OR 'ultras	
		onographic	
		examination' OR 'ultra	
		sonographic	
		screening' OR 'ultraso	
		nography' OR 'ultraso	
		und	
		diagnosis' OR 'ultraso	
		und scanning')	
		AND Cricothyroid	
		memorane /exp	
	membrane[Title/Abstract]))) OR ((Diagnosis/Broad[filter]) AND (cricothyroid membrane AND ultrasonography)) Resultados: 53 25/09/20 Búsqueda juntando mesh con título/abstract y clinical queries	gram' OR 'echographi c evaluation' OR 'echog raphy' OR 'echoscopy ' OR 'echosound' OR ' high resolution echography' OR 'scan ning, ultrasonic' OR 'sonog ram' OR 'sonographic examination' OR 'sonog raphy' OR 'ultrasonic detection' OR 'ultraso nic diagnosis' OR 'ultraso nic echo' OR 'ultrasonic examination' OR 'ultraso nic scanning' OR 'ultraso nic scintillation' OR 'ultra sonographic examination' OR 'ultra sonographic examination' OR 'ultra sonographic examination' OR 'ultraso nic screening' OR 'ultraso nographic examination' OR 'ultraso nographic examination' OR 'ultraso nographic examination' OR 'ultraso nography' OR 'ultraso und scanning') AND 'cricothyroid membrane'/exp	

Complementary material 2. Statistical analyses.

library(meta)

library(readxl)

Meta Análisis Detección Correcta con Ensayos Clínicos

```
metacric <- metabin(eventos_us, total_us, eventos_pal, total_pal,</pre>
                  data=dataC, method.tau= "ML", sm="RR", allstudies= TRUE, method="I", studlab=paste
metacric
## Number of studies combined: k = 6
## Number of observations: o = 593
## Number of events: e = 355
##
##
                             RR
                                          95%-CI
                                                    z p-value
## Common effect model 1.4349 [1.2620; 1.6316] 5.51 < 0.0001
## Random effects model 1.8777 [1.0491; 3.3606] 2.12 0.0339
##
## Quantifying heterogeneity:
## tau<sup>2</sup> = 0.4792 [0.1967; 4.2233]; tau = 0.6922 [0.4436; 2.0551]
## I<sup>2</sup> = 89.4% [79.6%; 94.5%]; H = 3.07 [2.22; 4.26]
##
## Test of heterogeneity:
##
        Q d.f. p-value
```

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```
## 47.24 5 < 0.0001
##
## Details on meta-analytical method:
## - Inverse variance method
## - Maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
forest(metacric, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours ultrasound", col.label.right = "green",
    label.left = "Favours palpation", col.label.left = "red",
```

```
prediction = FALSE)
```



Meta Análisis Fallas en detección con Ensayos Clínicos

metacricF1

```
## Number of studies combined: k = 6
## Number of observations: o = 593
## Number of events: e = 238
##
##
                             RR
                                          95%-CI
                                                      z p-value
## Common effect model 0.3345 [0.2607; 0.4291] -8.61 < 0.0001
## Random effects model 0.3804 [0.2372; 0.6101] -4.01 < 0.0001
##
## Quantifying heterogeneity:
##
   tau^2 = 0.1971 [0.0187; 3.6428]; tau = 0.4439 [0.1367; 1.9086]
   I<sup>2</sup> = 69.2% [27.4%; 86.9%]; H = 1.80 [1.17; 2.76]
##
##
## Test of heterogeneity:
##
        Q d.f. p-value
```

```
## 16.21 5 0.0063
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
forest(metacricF1, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours palpation", col.label.right = "red",
    label.left = "Favours ultrasound", col.label.left = "green",
    prediction = FALSE)
```

```
Experimental
                                                                                    Risk Ratio
                                    Control
                                                          Risk Ratio
                 Events Total Events Total Weight IV, Random, 95% CI
                                                                               IV, Random, 95% CI
Study
Kirskensen 2015
                      6
                           35
                                   22
                                         35
                                             16.5%
                                                       0.27 [0.13; 0.59]
Siddiqui 2015
                                              19.7%
                                                       0.62 [0.33; 1.14]
                       9
                           24
                                   14
                                         23
You-Ten 2015
                      14
                           56
                                   25
                                         56
                                             21.3%
                                                       0.56 [0.33; 0.96]
Forshaw 2018
                      2
                           10
                                               3.9%
                                    1
                                         11
                                                       2.20 [0.23; 20.72]
Siddiqui 2018
                     22
                          114
                                   100
                                        109
                                              24.8%
                                                       0.21 [0.14; 0.31]
Van Emden 2020
                                                       0.28 [0.11; 0.70]
                      5
                           60
                                   18
                                         60
                                              13.9%
Total (95% CI)
                          299
                                        294 100.0% 0.38 [0.24; 0.61]
Heterogeneity: Tau<sup>2</sup> = 0.1971; Chi<sup>2</sup> = 16.21, df = 5 (P < 0.01); I^2 = 69\%
                                                                            0.1
                                                                                    0.5 1 2
                                                                                                    10
```

```
Favours ultrasound Favours palpation
```

metacricF1h

```
## Number of studies combined: k = 5
## Number of observations: o = 572
## Number of events: e = 235
##
##
                             RR
                                           95%-CI
                                                       z p-value
## Common effect model 0.3267 [0.2542; 0.4198] -8.74 < 0.0001
## Random effects model 0.3543 [0.2221; 0.5654] -4.35 < 0.0001
##
## Quantifying heterogeneity:
   tau<sup>2</sup> = 0.1798 [0.0122; 1.8033]; tau = 0.4240 [0.1106; 1.3429]
##
   I<sup>2</sup> = 70.3% [24.3%; 88.3%]; H = 1.83 [1.15; 2.93]
##
##
## Test of heterogeneity:
##
        Q d.f. p-value
##
   13.46
             4 0.0092
```

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```
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
```

```
Meta Análisis Detección Correcta con Observacionales
```

```
metacricabs1 <- metabin(eventos_us, total_us, eventos_pal, total_pal,</pre>
                   data=dataC, sm="RD", method="I", studlab=paste(Estudio))
metacricabs1
## Number of studies combined: k = 6
## Number of observations: o = 593
## Number of events: e = 355
##
##
                             RD
                                           95%-CI
                                                      z p-value
## Common effect model 0.4676 [0.4059; 0.5293] 14.85 < 0.0001
## Random effects model 0.3040 [0.0779; 0.5300] 2.64
                                                          0.0084
##
## Quantifying heterogeneity:
## tau<sup>2</sup> = 0.0691 [0.0212; 0.4617]; tau = 0.2628 [0.1456; 0.6795]
## I<sup>2</sup> = 93.0% [87.5%; 96.1%]; H = 3.78 [2.83; 5.06]
##
## Test of heterogeneity:
        Q d.f. p-value
##
   71.55
           5 < 0.0001
##
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
forest(metacricabs1, layout = "RevMan5", fixed = FALSE,
  label.right = "Favours ultrasound", col.label.right = "green",
  label.left = "Favours palpation", col.label.left = "red",
  prediction = FALSE)
```

	Experimental		Co	ontrol		Risk Difference	Risk D	Difference	
Study	Events	Total	Events	Total	Weight	IV, Random, 95% CI	IV, Rand	om, 95% (CI
Kirskensen 2015	29	35	13	35	16.7%	0.46 [0.25; 0.66]			_
Siddiqui 2015	15	24	9	23	14.9%	0.23 [-0.04; 0.51]			_
You-Ten 2015	42	56	31	56	17.3%	0.20 [0.02; 0.37]			
Forshaw 2018	8	10	10	11	14.4%	–0.11 [–0.41; 0.19]			
Siddiqui 2018	92	114	9	109	18.7%	0.72 [0.64; 0.81]			
Van Emden 2020	55	60	42	60	18.0%	0.22 [0.08; 0.35]			
		200		204	100.09/	0 20 [0 00, 0 52]			
	2 0.000			- -					
Heterogeneity: Tau	= 0.069	i; Chi	= 71.55, 0	df = 5 (P < 0.01)	1 = 93%	0.5	,	
							-0.5	0 (J.5

Favours palpation Favours ultrasound

Meta Análisis fallas en identificación con Observacionales

metacricF2

```
## Number of studies combined: k = 9
## Number of observations: o = 1553
## Number of events: e = 458
##
##
                                          95%-CI
                             RR
                                                      z p-value
## Common effect model 0.5549 [0.4440; 0.6937] -5.17 < 0.0001
## Random effects model 0.1080 [0.0274; 0.4253] -3.18
                                                          0.0015
##
## Quantifying heterogeneity:
## tau<sup>2</sup> = 3.4646 [1.0663; 15.2664]; tau = 1.8613 [1.0326; 3.9072]
   I<sup>2</sup> = 82.3% [67.8%; 90.3%]; H = 2.38 [1.76; 3.22]
##
##
## Test of heterogeneity:
        Q d.f. p-value
##
   45.32 8 < 0.0001
##
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
## - Continuity correction of 0.5 in studies with zero cell frequencies
forest(metacricF2, layout = "RevMan5", fixed = FALSE,
 label.right = "Favours palpation", col.label.right = "red",
  label.left = "Favours ultrasound", col.label.left = "green",
 prediction = FALSE)
```







metacric_obs

Number of studies combined: k = 9

```
## Number of observations: o = 1553
## Number of events: e = 1095
##
##
                             RR
                                           95%-CI
                                                       z p-value
## Common effect model 1.5701 [1.4675; 1.6798] 13.09 < 0.0001
## Random effects model 1.7615 [1.3601; 2.2813] 4.29 < 0.0001
##
## Quantifying heterogeneity:
   tau<sup>2</sup> = 0.1332 [0.0487; 0.6034]; tau = 0.3649 [0.2207; 0.7768]
##
   I<sup>2</sup> = 89.2% [81.7%; 93.6%]; H = 3.04 [2.34; 3.96]
##
##
## Test of heterogeneity:
        Q d.f. p-value
##
   74.08 8 < 0.0001
##
##
## Details on meta-analytical method:
## - Inverse variance method
## - Restricted maximum-likelihood estimator for tau<sup>2</sup>
## - Q-profile method for confidence interval of tau<sup>2</sup> and tau
## - Continuity correction of 0.5 in studies with zero cell frequencies
```

```
forest(metacric_obs, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours ultrasound", col.label.right = "green",
    label.left = "Favours palpation", col.label.left = "red",
    prediction = FALSE)
```

	Experim	nental	C	ontrol		Risk Ratio		Risk Ratio
Study	Events	Total	Events	Total	Weight	IV, Random, 95% C		IV, Random, 95% CI
Aslany 2012	56	56	13	56	9.2%	4.19 [2.63; 6.67]		
Barbe 2014	24	24	10	24	9.3%	2.33 [1.48; 3.69]		
Lamb 2015	186	186	79	186	12.4%	2.35 [1.99; 2.77]		
Yildiz 2016	83	120	80	120	12.3%	1.04 [0.87; 1.23]		₽
Betul Basaran 2018	8 80	80	44	80	12.2%	1.81 [1.49; 2.20]		
Oh 2018	123	123	87	123	12.8%	1.41 [1.26; 1.58]		
Altun 2019	82	110	50	110	11.8%	1.64 [1.30; 2.07]		
Bowness 2020	25	33	42	66	11.5%	1.19 [0.91; 1.55]		
Lavelle 2021	20	28	11	28	8.6%	1.82 [1.08; 3.05]		
Total (95% CI)		760		793	100.0%	1.76 [1.36; 2.28]		•
Heterogeneity: Tau ² =	= 0.1332; 0	Chi ² = 7	74.08, df =	= 8 (P <	< 0.01); l ²	= 89%		
							0.2	0.5 1 2

Favours palpation Favours ultrasound

5

metacric_obsabs2

Number of observations: o = 1553 ## Number of events: e = 1095 ## ## RD 95%-CI z p-value ## Common effect model 0.4172 [0.3799; 0.4545] 21.91 < 0.0001 ## Random effects model 0.3832 [0.2264; 0.5399] 4.79 < 0.0001 ## ## Quantifying heterogeneity: $tau^2 = 0.0521 [0.0209; 0.2002]; tau = 0.2282 [0.1446; 0.4474]$ ## I² = 93.6% [89.9%; 95.9%]; H = 3.95 [3.15; 4.95] ## ## ## Test of heterogeneity: ## Q d.f. p-value 8 < 0.0001 ## 124.59 ## ## Details on meta-analytical method: ## - Inverse variance method ## - Restricted maximum-likelihood estimator for tau² ## - Q-profile method for confidence interval of tau² and tau ## - Continuity correction of 0.5 in studies with zero cell frequencies

```
forest(metacric_obsabs2, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours ultrasound", col.label.right = "green",
    label.left = "Favours palpation", col.label.left = "red",
    prediction = FALSE)
```

	Experim	ental	Co	ontrol		Risk Difference			
Study	Events	Total	Events	Total	Weight	IV, Random, 95% CI			
Aslany 2012	56	56	13	56	11.5%	0.77 [0.65; 0.88]			
Barbe 2014	24	24	10	24	10.2%	0.58 [0.38; 0.78]			
Lamb 2015	186	186	79	186	12.0%	0.58 [0.50; 0.65]			
Yildiz 2016	83	120	80	120	11.5%	0.03 [-0.09; 0.14]			
Betul Basaran 2018	80	80	44	80	11.6%	0.45 [0.34; 0.56]			
Oh 2018	123	123	87	123	11.9%	0.29 [0.21; 0.37]			
Altun 2019	82	110	50	110	11.4%	0.29 [0.17; 0.41]			
Bowness 2020	25	33	42	66	10.5%	0.12 [–0.07; 0.31]			
Lavelle 2021	20	28	11	28	9.4%	0.32 [0.08; 0.57]			
Total (95% Cl) 760 793 100.0% 0.38 [0.23; 0.54]									
Heterogeneity: Tau ² = 0.0521; Chi ² = 124.59, df = 8 (P < 0.01); I ² = 94%									





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```
forest(metacricsens1, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours palpation", col.label.right = "red",
    label.left = "Favours ultrasound", col.label.left = "green",
    prediction = FALSE)
```



```
metacricsens2
```

Number of studies combined: k = 6 ## Number of observations: o = 1147 ## Number of events: e = 365 ## ## 95%-CI R.R. z p-value ## Common effect model 0.5943 [0.4744; 0.7445] -4.53 < 0.0001 ## Random effects model 0.2593 [0.0787; 0.8548] -2.22 0.0266 ## ## Quantifying heterogeneity: tau² = 1.7688 [0.6972; 29.8173]; tau = 1.3299 [0.8350; 5.4605] ## I² = 81.3% [59.9%; 91.3%]; H = 2.31 [1.58; 3.38] ## ## ## Test of heterogeneity: ## Q d.f. p-value 5 < 0.0001 ## 26.71 ## ## Details on meta-analytical method: ## - Inverse variance method ## - Maximum-likelihood estimator for tau² ## - Q-profile method for confidence interval of tau² and tau ## - Continuity correction of 0.5 in studies with zero cell frequencies

```
forest(metacricsens2, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours palpation", col.label.right = "red",
    label.left = "Favours ultrasound", col.label.left = "green",
    prediction = FALSE)
```



metacricsens3

Number of studies combined: k = 4 ## Number of observations: o = 250 ## Number of events: e = 157 ## ## RR 95%-CI z p-value ## Common effect model 1.3337 [1.1042; 1.6110] 2.99 0.0028 ## Random effects model 1.3891 [0.9982; 1.9330] 1.95 0.0513 ## ## Quantifying heterogeneity: tau² = 0.0690 [0.0044; 2.0343]; tau = 0.2627 [0.0662; 1.4263] ## I² = 70.9% [16.9%; 89.8%]; H = 1.85 [1.10; 3.13] ## ## ## Test of heterogeneity: Q d.f. p-value ## 3 0.0161 ## 10.31 ## ## Details on meta-analytical method: ## - Inverse variance method ## - Maximum-likelihood estimator for tau² ## - Q-profile method for confidence interval of tau² and tau

```
forest(metacricsens3, layout = "RevMan5", fixed = FALSE,
    label.right = "Favours ultrasound", col.label.right = "green",
    label.left = "Favours palpation", col.label.left = "red",
    prediction = FALSE)
```





