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Diagnostic Accuracy of Abdominal Ultrasonographic Sliding Sign in the Evaluation of Severe Intra-Abdominal Adhesions involving the Uterus in Women Undergoing Repeat Cesarean Delivery

Systematic review and meta-analysis

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Abstract

We aimed to assess diagnostic accuracy of transabdominal ultrasonography(TAS) sliding sign in diagnosing severe intra-abdominal adhesions with repeated Cesarian Delivery(CD). We comprehensively searched PubMed, Google Scholar, Web of Science, and Scopus for published studies till October 2022 that evaluated the sliding sign as a predictor of intra-abdominal adhesions after repeat CD. We used STATA and Comprehensive Meta-Analysis for meta-analysis. Seven studies(1318 patients) were eligible for inclusion. For identifying severe intra-abdominal adhesions, sliding sign on TAS had a combined sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio of 64%(95% CI, 55-71%),

93%(95% CI, 89-96%), 9.5(95% CI, 5.7-16), 0.39(95% CI, 0.31-0.49), and 24(95% CI, 13-46), respectively. Prediction intervals for sensitivity and specificity were 0.444 to 0.786 and 0.711 to 0.985, respectively. We concluded that sliding sign on TAS is a simple, non-invasive, good negative and practical method to exclude severe intra-abdominal adhesions involving the uterus with low sensitivity and high specificity.
Keywords: Sliding Sign; Sonography; Cesarean; Adhesions.

Introduction

One of the commonest obstetric procedures is cesarean delivery (CD), representing approximately 30% of all births.[1,2] This dramatic increase in CD rates can be attributed to rising multiple pregnancy rates, maturing mothers, and medico-legal concerns.[3–5]
Postoperative adhesions, a potential complication of any surgery including CDs,[6] occur in 24–83% of cases.[7] Postoperative adhesions might result in small intestinal obstruction, [8–10] infertility, challenging repeat surgeries, and chronic abdominal pain. Therefore, it is crucial to accurately diagnose the degree of preexisting pelvic adhesions to properly plan subsequent operative procedures and forecast the likelihood of postoperative adhesion formation.[11]

Intra-abdominal adhesions following CD are common and can be hazardous upon abdominal re-entry, often forming between the uterus and bladder or abdominal wall. The severity and scoring of intra-abdominal adhesions are usually higher with increasing cesarean deliveries. In the study by Tulandi et al.[12] involving 1,026 women, dense adhesions were significantly higher after≥2 CDs (46.3% and 48.2%) than after one CD (29.8% and 25.6%). Post-adhesion consequences include complicated repeat abdominal surgeries, bowel or bladder injury, hemorrhage, lengthier surgery, a higher chance of hysterectomy, infections, and poor neonatal outcomes.[13,14]

There is currently no dependable approach to predict the existence of intra-abdominal adhesions.[15] Intra-abdominal adhesions are primarily predicted by skin scar texture, degree of striae gravidarum, and uterine thickness on ultrasonography.[16] The sliding sign on real-time ultrasound may indicate severe pelvic endometriosis with high accuracy and repeatability.[17] Baron et al.[18] extended this method for predicting substantial adhesions in women with repeat CDs.

Methods

Information sources

Preferred Reporting Items for the Systematic Review and Meta-analysis of Diagnostic Test Accuracy Studies (PRISMA-DTA) guidelines were used to write up this systematic review and meta-analysis.[19] The PRISMA-DTA Checklist is provided in Supplementary 1.

Eligibility criteria

Before beginning the database search, we determined the inclusion and exclusion criteria for studies in addition to data extraction & quality assessment method. Search strategies for all searched databases are provided in Supplementary 2.

Search strategy

We performed the search process using the following terms (c-section, C-Sections, Cesarean, Adhesions, Surgery Induced Tissue Adhesions, sliding sign). We included all studies published from the inception of each database until October 2022 with no restrictions applied.

Study Selection

The authors considered studies for eligibility if the population was gravida women with at least one prior cesarean delivery, the diagnostic test was the absence of sliding sign in trans-abdominal ultrasonography, the reference test was surgical reports following cesarean delivery, and the outcome was existence of intra-abdominal adhesions involving the uterus. Intraabdominal adhesions in included studies involved any adhesions related to the access of the surgeons to the planned uterine incision; it might involve thin, filmy, and easily separated adhesions by gentle, blunt, manual dissection with no vascular structures or adhesions between bowel or bladder and anterior uterine side making access to the lower uterine segment difficult and often require sharp dissection to release. Based on intraoperative findings, four levels of adhesions were identified: absent, mild (little or filmy adhesions), moderate (moderate to thick adhesions, require sharp dissection but do not involve bladder or bowel), and severe (absence of free space between uterine and abdominal walls or adhesions between uterus and bladder or bowel). A freely moving uterus indicated a low chance of adhesions (positive sliding sign). No

uterine movement under the fascia of abdominal muscles suggested severe adhesions (negative sliding sign). US findings were compared to surgical reports following CD surgery as the reference standard test.

Eligible study designs were retrospective and prospective observational studies. Two authors independently performed title & abstract screening, then full texts were downloaded and tested for eligibility by the same authors independently. A third senior reviewer resolved any discrepancies in screening decisions.

Data Extraction

Two authors extracted the data independently using an Excel sheet. They classified the extracted data from the included studies into three separate domains. These domains included (1) summary study characteristics, (2) baseline characteristics, and (3) diagnostic accuracy results. A third author resolved disagreements in study selection or data collection processes.

Quality Assessment

Quality Assessment of Diagnosis Accuracy Studies-2 (QUADAS-2) was utilized to evaluate the risk of bias.[20] Selection of Patients, the index test, the reference standard, and flow and timing are four components of QUADAS-2 tool. We classified the included studies into low, unclear, or high risk of bias. Two co-authors independently assessed studies' quality; discussions solved controversies. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) method was also used to rate the strength of the evidence.[21]

Statistical Analysis

We performed the analysis using STATA 17 and Comprehensive Meta-Analysis Version 4. We used Meta-analytical Integration of Diagnostic Accuracy Studies (MIDAS)[23] & Metadta[24] commands for the statistical analyses.

Primary outcomes were sensitivity, specificity, positive likelihood ratio (LR+), negative likelihood ratio (LR-), and diagnostic odds ratio (OR). In the meta-analysis, we included studies that reported these metrics. Values of I2 ranging from 0 to 40%, 30 to 60%, 50 to 90%, and 75 to

100% suggest that heterogeneity is rather insignificant, moderate, substantial, and, considerable, in that order.[22] A summary receiver operating characteristic (sROC) curve and area under ROC curve (AUC) evaluated test performance. Posttest probabilities were shown on the Fagan nomogram. The LR test showed a P-value of <0.0001 for the fitted random effects compared to a fixed-effects model, demonstrating increased data fit by random effect model.

Results

Study Selection

We had 249 articles after the initial electronic database search. After removing 11 duplicate records, the remaining 238 articles were evaluated by title and abstract screening; 18 were eligible, and 220 were excluded because they did not match our methodology-based inclusion criteria. After reading their full texts, our meta-analysis finally included seven articles (Figure 1).

Study characteristics and outcomes

Seven trials between March 2018 and October 2022 were finally included in our meta-analysis. Of them, six studies[18,25–29] examined the sonographic prediction of intra-abdominal adhesions involving the uterus in patients having a repeat CD. One study used the sliding sign, stria gravidarum, & cesarean scar to predict intraperitoneal adhesion in repeat cesarean deliveries.[30] The study sample sizes ranged from 59 to 380 women who underwent at least one prior CD and were scheduled to undergo repeat CD. All studies were prospective observational studies. An experienced surgeon conducted surgery in five studies.[18,25,26,28,29] Surgeons in all included studies were blinded to the procedure; Table 1. Each study contained information about the patients' backgrounds. Table 2 provides a comprehensive description of the diagnostic outcomes and characteristics of the studies that were included.

The sliding sign's specificity varied from 80% to 97%, and its sensitivity in detecting severe intra-abdominal adhesion ranged from 25% to 76%. The PPV ranged from 30% to 84%. However, the NPV was between 85% and 98%. LR+ ranged from 3 to 22, and LR- ranged from 0.2 to 0.6. Supplementary Table 1 illustrates the diagnostic outcomes of the studies that were incorporated.

Quality of included studies

Quality assessment

According to QUADAS-2, all studies enrolled pregnant women with one or more prior CDs who underwent abdominal ultrasonographic examinations during the third trimester. In five included studies,[18,25–27,30], the method by which patients were assigned to receive each index test was not adequately described, posing a potential bias and low bias risk in the remaining two studies.[28,29]

For the index-test domain, ultrasound was judged unclear in three studies[27–29] because the index-test results were unclear when the threshold was used. The reference standard was likely to accurately classify the target condition in all trials. With respect to the time interval between the index test and the reference standard, all examined studies showed a minimal probability of bias in the flow and timing domain. The time taken between the CD and US was found to have no significant impact on the desired outcome (Supplementary Table 2).

Using the GRADE system, the evidence's overall quality was moderate. We downgraded the quality of evidence by one level because the method of patient selection in most studies was unclear. Also, two studies did not prescribe the threshold used for interpretation (Supplementary Table 3).

Applicability

Regarding their relevance, all studies were found to have included patients who are pertinent to the review topic matter. For the index test, all but one study[26] showed low concerns about their applicability. Regarding reference-standard domains, all research exhibited minor applicability problems [Figure 2].

Results of the transabdominal US sliding sign as a diagnostic test

For detecting severe intra-abdominal adhesions involving the uterus, the transabdominal ultrasound sliding sign had a combined pooled sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, and diagnostic odds ratio of 64% (95% CI, 55-71%), 93% (95% CI, 89-96%), 9.5 (95% CI, 5.7-16), 0.39 (95% CI, 0.31-0.49), and 24 (95% CI, 13-46), respectively (Supplementary Figure 1). Heterogeneity was not important for sensitivity (Cochran's Q, 7.191;

P = 0.304, I^2 = 17%) and substantial for specificity (Cochran's Q, 26.418; P = 0.00, I2 = 77%). The area under the sROC curve was 0.67 (95% CI, 0.62–0.71) (Supplementary Figure 2A). Prediction interval for the sensitivity was (0.444 to 0.786) and for the specificity was (0.711 to 0.985).

As demonstrated in Fagan nomogram (Supplementary Figure 3A), a negative sliding sign (positive test) in women undergoing repeat CD with suspected intra-abdominal adhesions involving the uterus raised the pretest likelihood of adhesions on CD from 48% to 90%, whereas a positive sliding sign (negative test) considerably lowered it from 48% to 27%.

Results after sensitivity analysis

After the leave-one-out test, Shu 2021 was excluded to solve the heterogeneity. Pooled sensitivity, specificity, positive LR, negative LR, and diagnostic OR were 64% (95% CI, 54-73%), 94% (95% CI, 92-96%), 10.7 (95% CI, 7.7-14.9), 0.38 (95% CI, 0.29-0.5), and 28 (95% CI, 18-45), respectively (Supplementary Figure 4). Heterogeneity was not important in either sensitivity (Cochran's Q, 6.519; P = 0.259, I^2 = 23%) or specificity (Cochran's Q, 7.701; P = 0.174, I2 = 35%). The area under sROC curve was 0.91 (95% CI, 0.88–0.93) (Supplementary Figure 2B). Prediction interval for the sensitivity was (0.407 to 0.829) and the prediction interval for the specificity was (0.865 to 0.972).

As demonstrated in Fagan nomogram (Supplementary Figure 3B), a negative sliding sign (positive test) in women undergoing repeat CD with suspected intra-abdominal adhesions involving the uterus raised the pretest likelihood of adhesions on CD from 48% to 91%, whereas a positive sliding sign (negative test) considerably lowered it from 48% to 26%.

Discussion

Summary of findings

In our meta-analysis, the uterine sliding sign in TAS had an acceptable sensitivity of 64% (95% CI, 55-71%) & a high specificity of 93% (95% CI, 89-96%) in detecting severe intra-abdominal adhesions involving the uterus in women with at least one prior cesarean delivery.

Interpretation of findings

Adhesion prediction is based mostly on the clinical assessment of past surgeries and the number of prior CDs. Preoperative transabdominal ultrasonography, while simple, may result in proper patient counseling for complications and careful planning for safer operations.[18] Prolonged operating timeframes (from cutaneous incision to delivery and total duration from skin incision to closure of skin) and a hemoglobin decrease of more than 3 g/dL are examples of surgical complications.[29] Recent studies have shown a correlation between the negative sliding sign, time between the skin incision and delivery,[27,29]and the capability to predict bleeding,[27] indicating more difficult surgery.

Ultrasound's sensitivity and specificity in identifying uterine intra-abdominal adhesions across studies varied from 54% to 70% and from 90% to 97%, respectively. This may be related to the number of previous CDs, parity, experience of the operators, and sample size. Baron et al.[18] showed the highest sensitivity and specificity (76% and 97%, respectively). This could be attributed to parity, which was highest in this study compared to the other included studies; approximately half of the sample size in the study had more than three previous CDs. In contrast, Shu et al.[26] demonstrated the lowest diagnostic performance with a sensitivity of 53% and specificity of 80%. These disparities may be ascribed to variations in baseline factors such as ethnicity, body mass index, and the number of prior cesarean deliveries.

Combining the sliding sign with the existence of a depressed scar, severe striae, or both might improve predictive accuracy. Mokhtari et al.[30] recommended the evaluation of adhesions by incorporating the sliding sign alongside a depressed scar, which had the highest positive predictive value (92%). Drukker et al.[29] also suggested combining a negative sliding sign with a history of adhesions after CD to predict severe intra-abdominal adhesions.

In a recently published meta-analysis, the use of ultrasonographic visceral sliding evaluation as a rule-out assessment test was validated with an adhesion rate of 14.4% and an NPV of 99.4% with slight variation across observations.[31] This finding is in line with our results that suggest the benefit of the sliding sign in excluding the existence of severe intra-abdominal adhesions without proven evidence in the diagnosis.

According to the literature, evaluating the sliding sign might only require a brief training period and be repeatable by skilled operators.[32] However, the capability to perform diagnostic methods depends on expertise, and not every trainee will become competent. Thus, further research is required with established standardization of exploratory methods for clear visualization and better sonographic performance. Additionally, reproducibility should be assessed along with the evaluation of the learning curve of trainees through a systematic training program.

Strengths and Limitations

Based on a literature search, we are the first meta-analysis to analyze TAS sliding sign diagnostic performance in identifying intra-abdominal adhesions involving the uterus. It has been reported according to the PRISMA-DTA statement, and Validated tools (QUADAS-2) assessed study quality. Additionally, the included studies are recent and can reflect the current implementation of ultrasonographic technology advancement. Another notable contribution of our review is using the GRADE system. Although all included studies were observational, we did not begin our Grade body of evidence with a low-certainty rating because we used a good quality assessment tool (QUADAS-2), and also, most of the studies assessing test diagnostic accuracy are observational in nature.

There are certain limitations, including Limited number of studies covered and their heterogeneity. Although most included trials reported that skilled surgeons performed the procedure, it was not mentioned how thoroughly the intra-abdominal adhesions were assessed. Additionally, the GRADE approach is primarily designed for interventions that might affect the quality of evidence for diagnostic testing.

Conclusion

Transabdominal ultrasound showed low sensitivity and high specificity in diagnosing severe intra-abdominal adhesions involving the uterus after repeat cesarean delivery compared to surgical reports following CD surgery as the reference standard test. The present evidence is insufficient to determine the efficacy of transabdominal ultrasound; however, women with a low risk of adhesions may find reassurance in the existence of a sliding sign. Our recommendation is

to use ultrasonography to rule out intra-abdominal adhesions affecting the uterus before CD, as it is a simple, non-invasive, practical, and easily accessible technique in most clinical settings.

Authors' Contribution

AMT, TJA and YAS handled data collection. WAM, SAAS and TJA performed the screening process and AMT resolved any conflicts. AMT performed the meta-analysis. WAM and SAAS performed quality assessment, while AMT resolved any conflicts. YAM assessed the quality of evidence using the GRADE system. WAM, AMT, SAAS, TJA and YAS drafted the manuscript. JLA, NAR, AK and AHS critically reviewed the manuscript. AMT, MA-E and YAM edited the manuscript. AHS supervised the work. All authors approved the final version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interests.

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Table 1: Summary of included studies.

Study ID	Study Design	Country	Sample size	Time of study conduction	Main inclusion criteria	Exclusion criteria
Baron 2018	Prospective observational study.	Italy	59	Between October 2015 and February 2017.	Pregnant women in the third trimester with at least one prior CD and scheduled to undergo CD in the current pregnancy.	known collagen disease.
Bukar 2022	Prospective, observational, triple-blind study.	Nigeria	67	Between May and November 2019.	Women in third trimester of pregnancy with at least one prior CD.	Non-consent, emergency CD, known collagen or muscular diseases, prior abdominopelvic surgeries other than CD.
Charernjiratragul 2022	Prospective cohort study.	Thailand	380	From January 2021 to February 2022	Singleton pregnant women aged >18 years, gestational age of 28-39 weeks, with at least one prior CD, scheduled for a repeat CD	BMI of >40 kg/m2, placenta previa or placenta accreta spectrum, and collagen diseases.
Drukker 2018	Prospective blind observational study.	Israel	370	Between March 2016 and December 2016.	Women with a scheduled repeat CD regardless of indication.	BMI >40 on admission and those with invasive placentation. Unplanned repeat CD because of urgency.

Mokhtari 2022	Prospective descriptive study	Iran	123	During 2019 and 2020.	Pregnant women with a gestational age ≥36 weeks candidates for CD because of a prior CD	Multiple pregnancies, wound infection, or endometritis after prior CDs, connective tissue diseases, a history of systemic disease or endometriosis, pelvic inflammatory disease, or any prior abdominal operation other than CD.
Nirumanesh 2020	Prospective observational study.	Iran	207	From January 2018 to January 2019.	Pregnant women with at least one previous CD in third trimester.	A known history of collagen diseases or placenta accreta spectrum.
Shu 2021	Prospective observational double-blinded study.	Hong Kong	112	Between November 2019 and May 2020.	Pregnant Chinese women in the third trimester with a history of one or more CDs.	known collagen disease, placenta accreta spectrum, and planned bilateral tubal ligation in the same setting.

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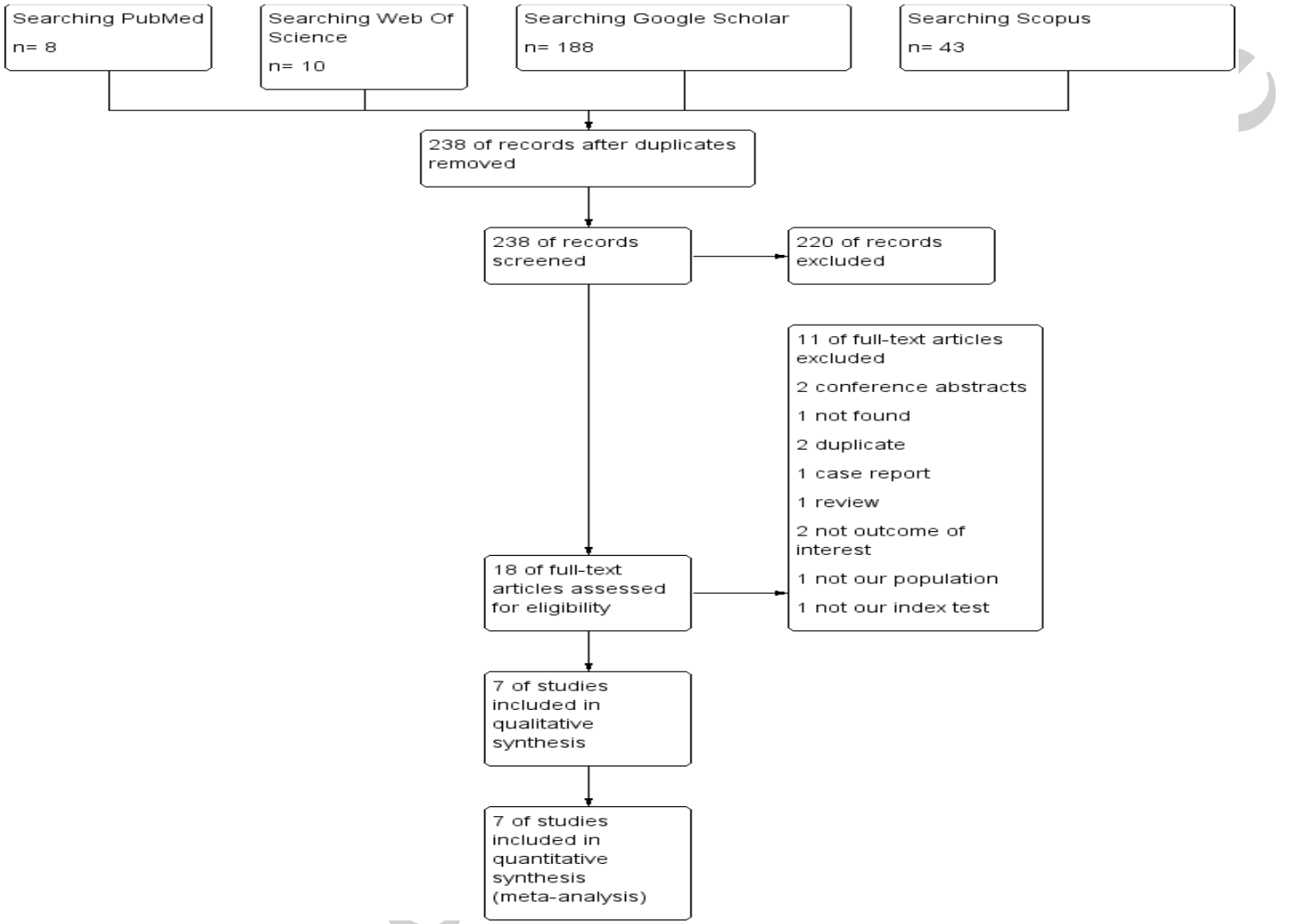
Table 2: Baseline characteristics of included studies.

	Maternal age		Gravity		Parity		Previous surgery		BMI		Gestational age at CD		Number of CD			
	mean	*SD*	*mean*	*SD*	*mean*	*SD*	*mean*	*SD*	*mean*	*SD*	*mean*	*SD*	1	2	3	4
Baron 2018	34.5	4.7	5.6	2.7	3.9	2.4	NM	NM	NM	NM	NM	NM	8	20	31 >2	NM
Bukar 2022	30.7	5.5	3.7	1.4	2.4	1.2	NM	NM	NM	NM	37.8	1.1	23	31	12	2 >3
Charernjiratragul 2022	33.7	4.2	NM	NM	NM	NM	NM	NM	28.2	4.2	34.7	7.52	306	63	11	NM
Drukker 2018	34.4	5.1	NM	NM	NM	NM	NM	NM	30.9	5.5	34.7	7.44	112	135	123 >2	NM
Mokhtari 2022	31.4	5.1	2.8	1.0	1.6	0.8	1.5	0.7	30.8	4.3	NM	NM	NM	NM	NM	NM
Nirumanesh 2020	33.4	4.7	2.9	1.1	1.5	0.8	0.2	0.4	27.1	4.2	35.2	3.2	NM	NM	NM	NM
Shu 2021	34.4	4.1	NM	NM	1.1	0.4	NM	NM	NM	NM	NM	NM	101	10	1	NM

BMI: Body mass index, SD: Standard deviation, NM: Not mentioned, CD: Cesarean delivery



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397 **Figure 1:** Flowchart of the study selection process

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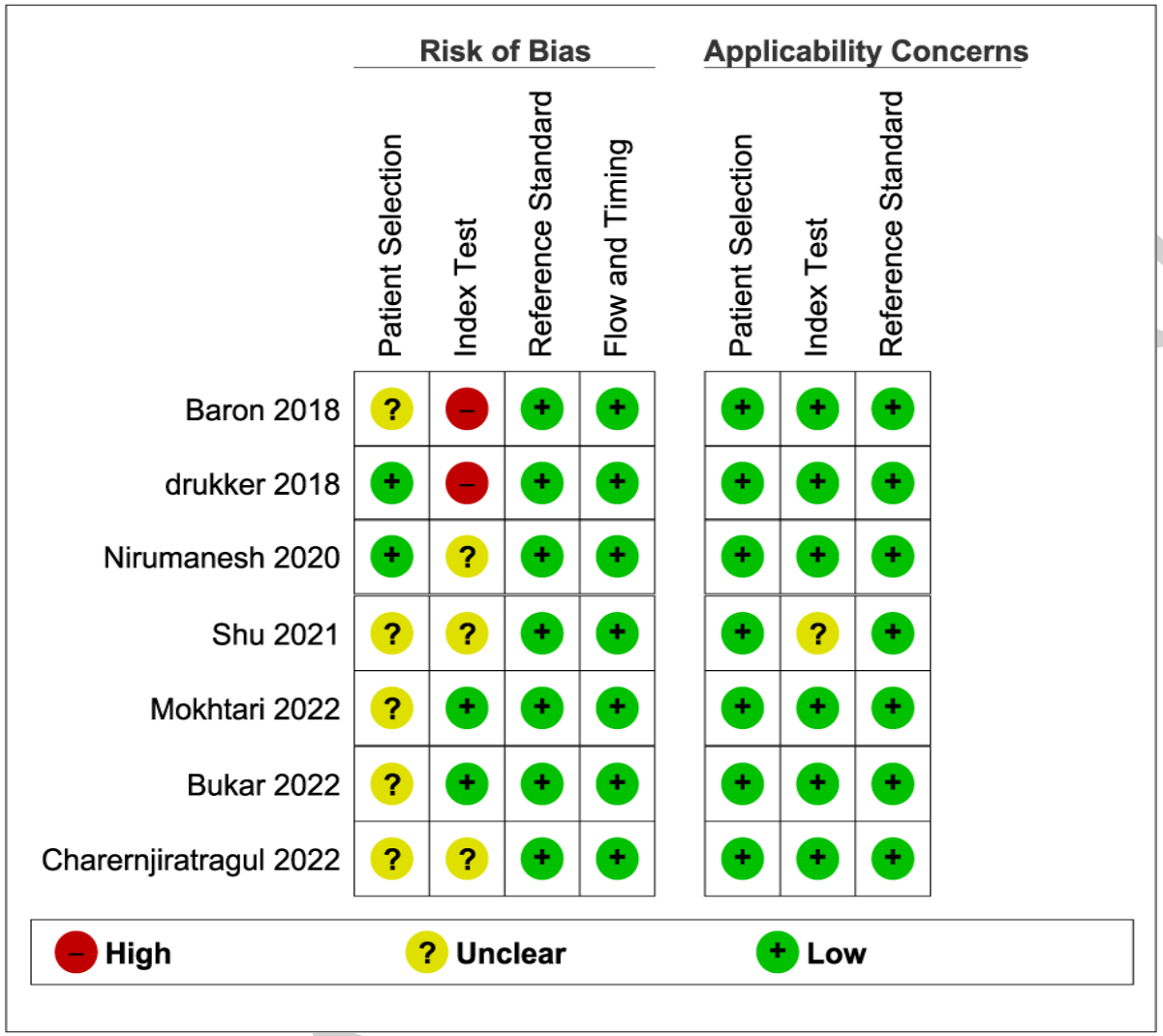

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400 **Figure 2:** Risk of bias graph for included studies according to quality assessment of diagnostic accuracy studies-2 (QUADAS-2) tool

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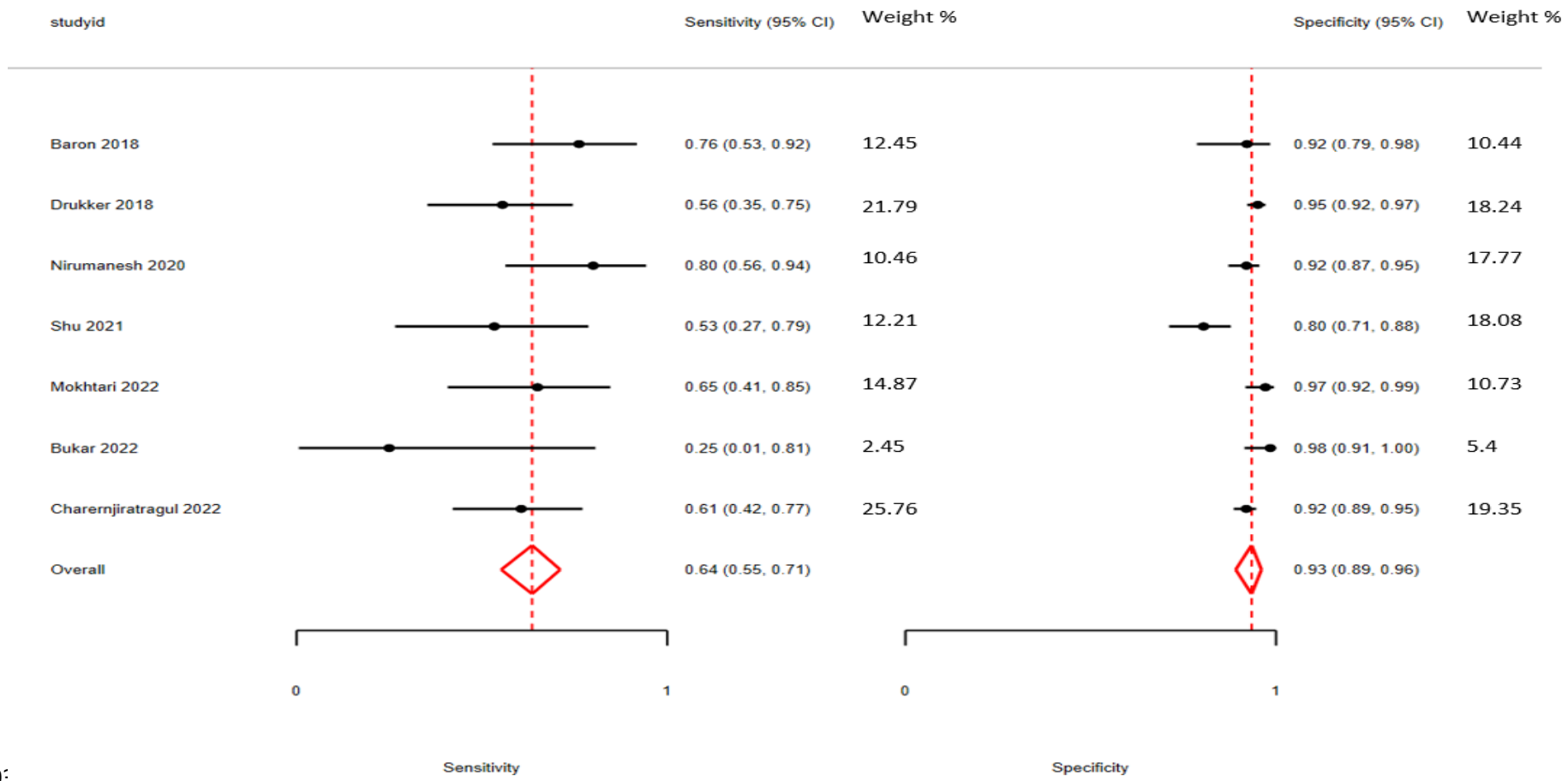
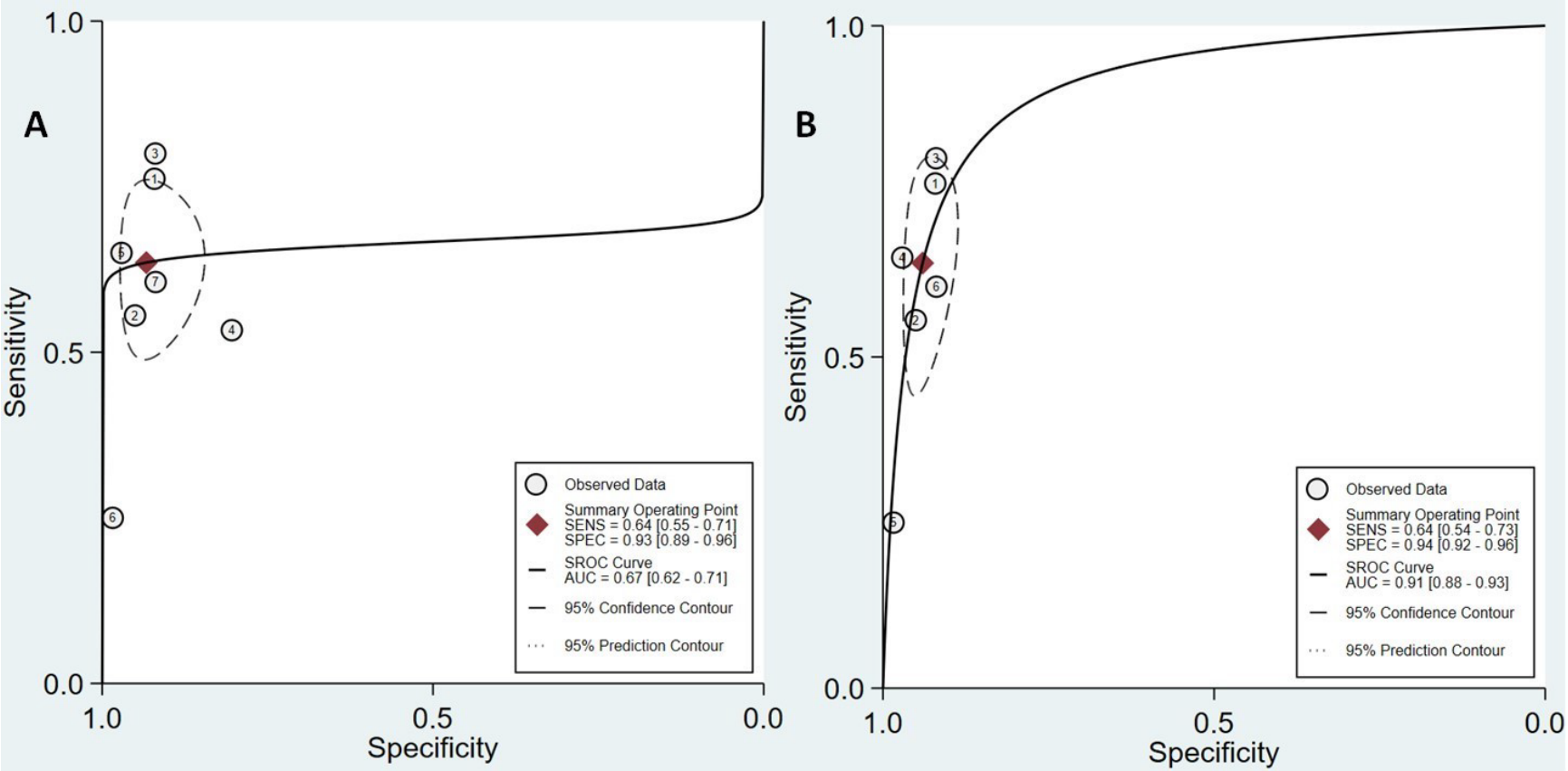
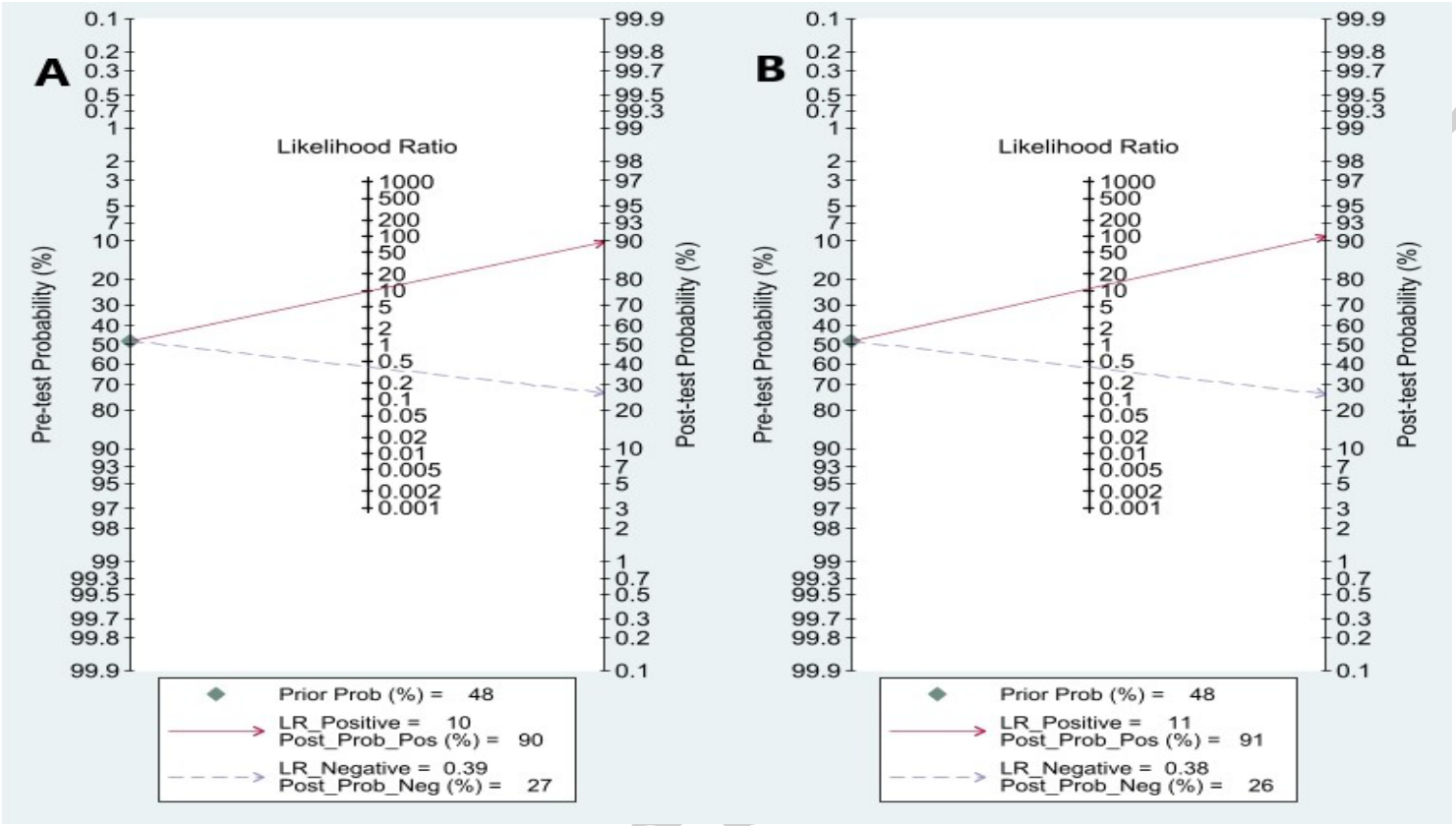


Supplementary Figure 1: Forest plot of the sliding sign on transabdominal ultrasound in the detection of severe intra-abdominal adhesions in women undergoing repeat cesarean delivery



Supplementary Figure 2: **A)** Summary receiver operating characteristic curve (sROC) of the sliding sign on transabdominal ultrasound in the detection of severe intra-abdominal adhesions in women undergoing repeat cesarean delivery

B) Summary receiver operating characteristic curve (sROC) of the sliding sign on transabdominal ultrasound in the detection of severe intra-abdominal adhesions in women undergoing repeat cesarean delivery after sensitivity analysis



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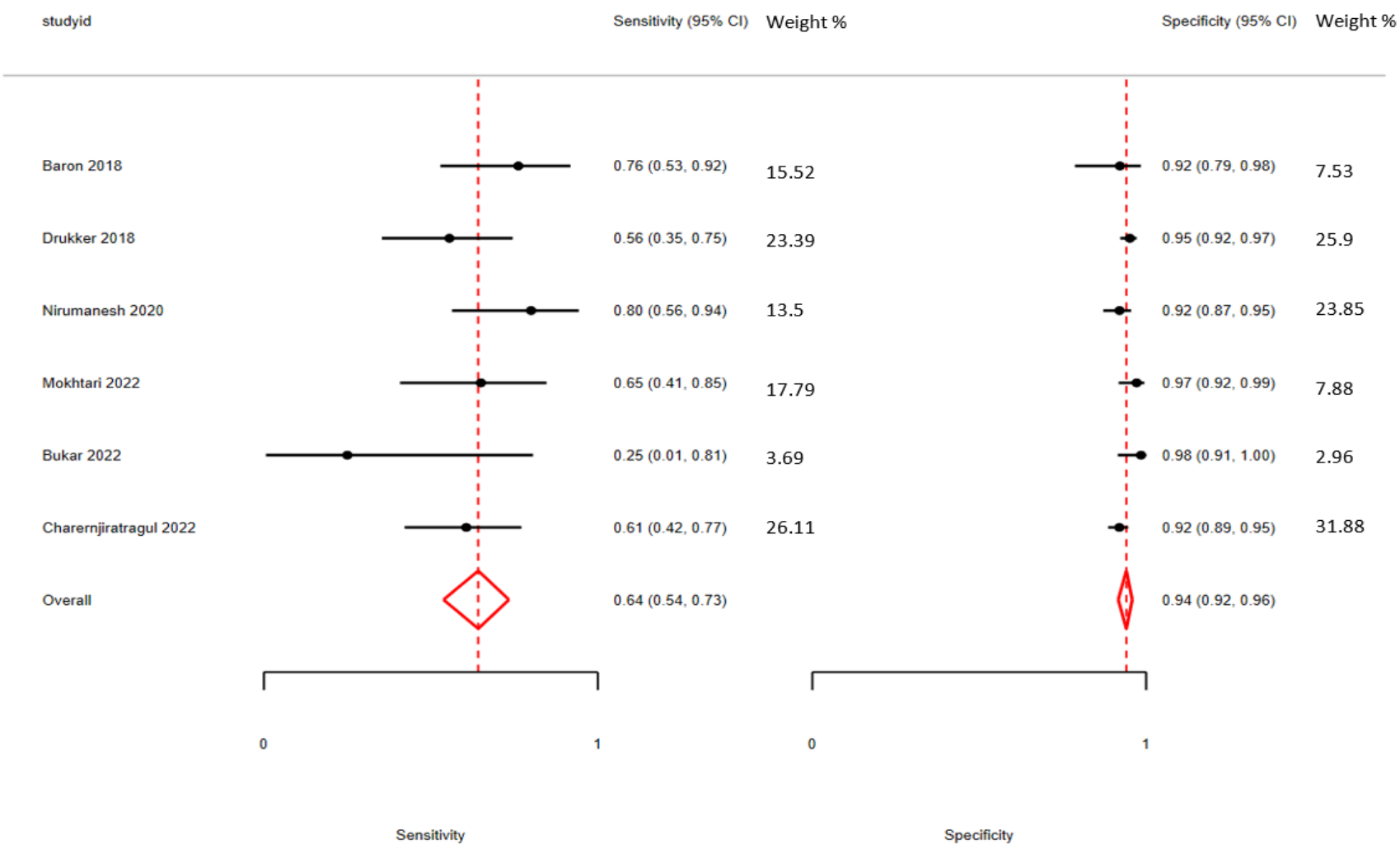
413 Supplementary Figure 3: A) Fagan nomograms for detecting severe intra-abdominal adhesions in women undergoing repeat cesarean

414 delivery based on negative and positive sliding sign on transvaginal ultrasound

415 B) Fagan nomograms for detecting severe intra-abdominal adhesions in women undergoing repeat cesarean delivery based on negative

416 and positive sliding sign on transvaginal ultrasound after sensitivity analysis.

417 LR−, negative likelihood ratio; LR+, positive likelihood ratio; prob, probability.



Supplementary Figure 4: Forest plot of the sliding sign on transabdominal ultrasound in the detection of severe intra-abdominal adhesions in women undergoing repeat cesarean delivery after sensitivity analysis.