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Evaluation of a Non-invasive Cervical Screening Tool for Difficult Embryo Transfer in Infertile Women: A Prospective Observational Diagnostic Study

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Abstract

Objectives: Embryo transfer is a critical stage in the in vitro fertilization (IVF) process, and cervical anatomy may contribute to procedural difficulty and reduced success rates. However, non-invasive and clinically applicable tools for predicting difficult transfer remain limited. This study aimed to assess the diagnostic performance of a non-invasive cervical screening tool for identifying difficult embryo transfer in infertile women.

Materials and Methods: This prospective observational diagnostic study (2025–2026) evaluated 308 infertile women referred to the infertility clinic of Shariati hospital, Tehran. Non-invasive cervical evaluation included visual inspection and transvaginal ultrasonography. Cervical anatomical indices, delivery history, and body mass index (BMI) were recorded. Embryo transfer was performed in a subsequent cycle by a specialist blinded to screening results. Difficult transfer was defined using predefined criteria. Data were analyzed using descriptive statistics, chi-square, and univariate logistic regression, with $P<0.05$ considered significant.

Results: Among 308 embryo transfers, 43 cases (13.96%) were classified as difficult transfers. Significant associations were observed between difficult embryo transfer and cervical position, external cervical os morphology, cervical canal visibility, obstetric history, cervical length, and number of miscarriages ($P < 0.05$). Severe cervical deviation was associated with approximately 17-fold higher odds of difficult embryo transfer (OR = 17.32). In comparison, a history of cesarean section without previous vaginal delivery was associated with approximately 5.75-fold higher odds of difficult transfer. The screening tool demonstrated high diagnostic performance with 88.4% sensitivity, 96.2% specificity, 79.2% positive predictive value, 98.1% negative predictive value, and an area under the curve (AUC) of 0.98.

Conclusions: The findings suggest that combining cervical anatomical features with obstetric history can provide a reliable pre-procedural assessment of transfer difficulty, with potential utility in clinical decision-making.

Keywords: Assisted reproductive technology, Embryo transfer, Infertility, In vitro fertilization

Introduction

Fertility is a fundamental biological function with important individual, familial, and social dimensions. For many couples, the ability to reproduce is closely associated with family identity and continuity (1).

In contrast, infertility is a complex and multidimensional disorder that extends beyond a physical condition and may impose significant psychological, emotional, and social burdens (2). It is defined as the inability to achieve pregnancy after 12 months of unprotected intercourse and is recognized as a global public health issue (3,4), affecting approximately 48 million couples worldwide (5).

Over the past four decades, assisted reproductive technologies (ARTs) have significantly advanced the management of infertility and enabled many couples to achieve pregnancy (6). These technologies involve the manipulation of oocytes or embryos outside the human body and include a range of techniques such as in vitro fertilization (IVF) (7,8).

Despite these advances, the success rate per ART cycle remains relatively modest (approximately 20%–30%) (9,10). It is influenced by multiple factors, including female age, underlying causes of infertility, embryo quality, endometrial receptivity, and procedural techniques (11). Among these factors, embryo transfer represents a critical step in the IVF process, as it directly affects implantation and clinical pregnancy outcomes. Optimal embryo transfer requires accurate placement of embryos within the uterine cavity with minimal trauma and uterine disturbance (12).

Implantation is a dynamic, multistep process dependent on complex embryo-endometrium interactions, and despite substantial advances in reproductive science, its regulatory mechanisms have not yet been fully elucidated (13-15). Beyond the morphological quality and developmental potential of the transferred embryos, as well as endometrial receptivity, the manner of execution

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and technical conditions of embryo transfer may independently influence implantation outcomes (15,16). Difficult embryo transfer and the presence of blood or blood-stained discharge on the transfer catheter, as potential indicators of tissue trauma, have been associated with reduced implantation rates and decreased pregnancy rates following embryo transfer (17).

Achieving an easy and atraumatic embryo transfer is therefore essential for improving ART outcomes. However, anatomical variations of the cervix and reproductive tract may render the procedure technically challenging, even for experienced clinicians (13).

Evidence indicates that difficult embryo transfer is associated with lower clinical pregnancy and live birth rates. Therefore, identifying patients at risk for difficult transfer prior to the procedure is of considerable clinical importance (13,18-21).

Such prediction enables appropriate planning, including the involvement of more experienced clinicians, use of adjunctive techniques, or further diagnostic evaluation, thereby minimizing complications and improving efficiency and overall procedural outcomes in clinical settings (19). One of the most debated topics in reproductive medicine is how to improve implantation rates and, consequently, pregnancy rates, which can be achieved through optimization of the embryo transfer technique. Various strategies have been proposed, including the use of different types of catheters, ultrasound-guided embryo transfer, and transfer to the fallopian tube (18).

Given the critical role of embryo transfer in ART success, developing a simple, noninvasive tool to identify patients at risk of difficult transfer is essential. Early identification enables targeted interventions that may improve implantation and outcomes. Therefore, this study aimed to evaluate a non-invasive cervical screening tool for the identification of difficult embryo transfer in infertile women undergoing IVF treatment at Shariati Hospital, Tehran.

Materials and Methods

Study Design and Participants

This prospective observational diagnostic study was conducted in 2025–2026 at the infertility clinic of Shariati Hospital, Tehran, Iran. Women who attended the infertility clinic for assisted reproductive treatment and were candidates for embryo transfer were assessed for eligibility.

Inclusion criteria were women aged 18-49 years who were candidates for either fresh embryo transfer or frozen embryo transfer cycles; diagnosis of infertility, defined as failure to achieve pregnancy after at least 12 months of unprotected intercourse, confirmed based on clinical records by a reproductive specialist; candidacy for ET within the planned treatment cycle, as determined by the treating physician; and provision of written informed consent prior to participation. Exclusion criteria included: withdrawal of consent or unwillingness to continue participation at any stage of the study, documented through patient request; undergoing ART for indications other than ET (e.g., fertility preservation), as identified from medical records; and presence of medical conditions contraindicating transvaginal ultrasonography. To ensure transparency and reproducibility, all inclusion and exclusion criteria were defined a priori and assessed at baseline through patient interviews, medical record review, and clinical evaluation by a reproductive specialist. A total of 308 eligible women were included in the study.

Sample Size Calculation

The sample size was initially calculated based on an expected proportion of difficult embryo transfer of 9%, as reported by Ata et al (19), using 80% statistical power. The minimum required sample size was 278 participants. Considering potential attrition, the final target sample size was increased to 308 participants. The diagnostic performance of the prespecified ART-ET composite score was subsequently evaluated in these participants.

Data Collection and Cervical Assessment

The ART-ET screening tool developed by Ata et al (19) was used in this study to assess factors associated with difficult embryo transfer. The same variables and scoring system described in the original study were used.

On the day of oocyte retrieval, demographic, clinical, and obstetric information was collected, and the cervical assessment was performed as part of the screening procedure. One trained infertility fellowship trainee performed all screening assessments.

Before vaginal cleansing, the cervix was visually assessed for its position and external os appearance according to the predefined screening criteria. Transvaginal ultrasonography was subsequently used to evaluate the cervical canal, including its length, course, and visibility. Cervical length was measured between the external and internal os along the canal.

The collected information included age, body mass index (BMI), pregnancy history, number and type of previous deliveries, number of miscarriages, previous embryo-transfer history, and history of previous cervical procedures. All findings were recorded in a predefined data collection form at the time of the screening assessment.

Embryo transfer was performed subsequently by an infertility specialist who was not involved in the screening assessment and was unaware of the screening results. The difficulty of embryo transfer was assessed at the time of the procedure according to the predefined study criteria and was recorded immediately after completion of the transfer.

ART-ET Scoring System

The ART-ET scoring system reported by Ata et al. (19) was used without modification. Each scored variable was

assigned a score according to the original criteria. Cervical canal length was not a component of the original ART-ET scoring system and was therefore not included in the total ART-ET score.

The scoring system for the non-invasive screening tool was defined as follows: BMI was scored as 0 for values below 25 kg/m², 1 for values between 25 and 29.9 kg/m², and 2 for values of 30 kg/m² or higher. Cervical position was scored as 0 for a central position, 1 for a decentralized position, and 2 for a marked or severely deviated position. For external os status, a dilated/parous os was scored 0, a normal os 1, and a pinpoint os 2. For sonographic appearance of the cervical canal, a straight and fully visualized canal received a score of 0, whereas a tortuous and incompletely visualized canal received a score of 2. Regarding obstetric history, a history of vaginal delivery was scored 0, nulliparity 1, and a history of cesarean section or cesarean scar defect 2.

The total screening score was calculated as the sum of BMI, cervical position, external os status, obstetric history, and sonographic appearance of the cervical canal. The restricted screening score included cervical position, sonographic appearance of the cervical canal, and obstetric history. The expanded screening score was calculated by adding cervical canal length to the restricted screening score. The cervical ultrasound score included sonographic appearance of the cervical canal and cervical canal length.

Embryo Transfer and Assessment of Transfer Difficulty

Fresh embryo transfers were performed during the same treatment cycle, whereas frozen embryo transfers were performed in subsequent cycles according to the treatment plan. All embryo transfers were performed by a single infertility subspecialist working at the infertility center. The same procedure was followed for all patients in accordance with established principles of infertility care. The physician performing the embryo transfer was not involved in the cervical screening assessment or transvaginal ultrasonography and was blinded to the screening findings and the total ART-ET score. The same type and model of embryo-transfer catheter was used throughout the study.

Immediately after embryo transfer, the physician recorded whether the procedure was easy or difficult. The definition of difficult embryo transfer was established before data collection and was applied consistently throughout the study. An embryo transfer was classified as difficult if one or more of the following criteria were present: use of an obturator to guide the catheter toward the internal cervical os, use of forceps to manipulate the cervix, presence of blood on the catheter after the procedure, the need to reload the catheter, or the physician's assessment that the transfer was difficult. All transfer-related findings were recorded immediately after the procedure using a standardized checklist.

ART-ET Screening Tool

The ART-ET screening tool used in this study was developed and previously reported by Ata et al (19). The same screening variables and scoring criteria were used in the present study without modification.

To maintain consistency in the assessment of the screening variables, all clinical cervical examinations and transvaginal ultrasonographic assessments were performed by the same trained infertility fellow using predefined assessment criteria. The screening assessment was performed independently of the embryo-transfer procedure. The physician performing the embryo transfer was blinded to the screening findings and the total ART-ET score.

Internal consistency was not assessed because the ART-ET score includes different clinical and anatomical variables that contribute to the prediction of difficult embryo transfer.

Scoring Systems and Determination of Cut-off Value

The ART-ET screening tool was evaluated using four scoring systems: the Total screening score, Restricted screening score, Expanded screening score, and Cervical ultrasound score. The Total screening score was calculated according to the ART-ET scoring system reported by Ata et al (19), without modification.

Cervical canal length was not included in the total or restricted screening scores. It was incorporated into the Expanded screening score and the Cervical ultrasound score as an additional sonographic component. The remaining scoring components were assessed according to the criteria described by Ata et al (18).

The cut-off values were ≥5 for the Total screening score, ≥3 for the Restricted screening score, ≥3 for the Expanded screening score, and ≥2 for the Cervical ultrasound score. Participants with a score equal to or above the corresponding cut-off were classified as having a predicted difficult embryo transfer. In contrast, those with a score below the cut-off were classified as having a predicted easy embryo transfer.

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences, version 17.0, SPSS Inc., Chicago, Illinois, USA. Descriptive statistics, including mean, standard deviation, median and interquartile range, frequency, and percentage, were used to summarize the study variables. The Chi-square test was used to assess the association between categorical variables and the difficulty of embryo transfer. Univariable logistic regression analysis was performed to evaluate the association between demographic, obstetric, and screening variables and difficult embryo transfer. The diagnostic performance of the total ART-ET score was evaluated using sensitivity, specificity, positive predictive value, negative predictive value, and overall accuracy. The area under the curve (AUC) was calculated to assess the

ability of the total ART-ET score to discriminate between easy and difficult embryo transfers. A *P* value of <0.05 was considered statistically significant.

Results

According to the findings presented in Table 1, a total of 308 embryo transfers were evaluated.

The mean age of participants was 34.22 years. Cervical length ranged from 28 to 42 mm. Regarding obstetric history, 247 participants (80.19%) were nulliparous. Additionally, 238 participants (77.27%) were undergoing their first embryo transfer cycle. Based on the predefined criteria of the study, 43 cases (13.96%) were classified as difficult transfers, while 265 cases (86.04%) were classified as easy transfers.

The frequency distribution of the screening tool parameters is presented in Table 2. The most frequent categories for each variable were as follows: BMI less than 25 kg/m² in 156 participants (50.65%), central cervical position in 272 participants (88.31%), normal appearance of the external cervical os in 268 participants (87.01%), straight cervical canal on ultrasonography assessment in 270 participants (87.66%), and nulliparity in 247 participants (80.19%).

The results of the Chi-square test, presented in Table 3, demonstrated a statistically significant association between cervical position, external cervical os morphology, ultrasonography appearance of the cervical canal, and obstetric history with difficult embryo transfer ($P < 0.05$).

Specifically, in the difficult transfer group, severe cervical deviation, pinpoint external os, and tortuous cervical canal were significantly more frequent than in the easy transfer group.

Table 4 presents the results of the univariable logistic regression analysis examining the association between individual demographic, obstetric, and screening tool parameters and difficult embryo transfer. Cervical position, external cervical os, obstetric history, cervical length, and number of miscarriages were significantly associated with difficult embryo transfer. The tortuous/not-visible cervical canal variable was not included in the logistic regression analysis because all 38 participants with this finding were in the difficult-transfer group, while none were in the easy-transfer group, resulting in complete separation.

The prespecified ART-ET total score was also evaluated separately as a composite screening score to assess its overall association with difficult embryo transfer.

Participants with a decentralized cervix had approximately 7-fold higher odds of difficult embryo transfer compared with those with a central cervix. In comparison, those with a severely deviated cervix had approximately 17-fold higher odds. Regarding the external cervical os, participants with a normal os had approximately 96% lower odds of difficult embryo transfer compared with those with a dilated/parous os. The pinpoint category was not included in the logistic regression analysis because of the small number of cases. A history of cesarean section without previous vaginal delivery was associated with approximately 5.75-fold higher odds of difficult embryo transfer compared with a history of vaginal delivery. Cervical length was also significantly associated with difficult embryo transfer;

Table 1. Obstetric Demographic Characteristics of the Study Samples

Variable	Mean ± SD	MD (IQR)	Min	Max
Age	34.22 ± 5.65	34 (8)	18	49
Number of pregnancies	0.538 ± 0.870	0 (1)	0	5
Cervical length	34.85 ± 2.51	34 (4)	28	42
Variable		**n (%)**		
Parity				
0		247 (80.19)		
1		58 (18.83)		
2 or more		3 (0.97)		
Number of abortions				
0		236 (76.62)		
1		55 (17.86)		
2		10 (3.25)		
3 or more		7 (2.26)		
Type of transfer				
Easy		265 (86.04)		
Difficult		43 (13.96)		
Number of transfers				
First		238 (77.27)		
Second or more		70 (22.73)		

SD, standard deviation; IQR, interquartile range; MD, Median.

Table 2. Descriptive Statistics of the Screening Tool in the Study Samples

Variable	n (%)
Body mass index	
Less than 25 kg/m²	156 (50. 65)
25-29.9 kg/m²	122 (39. 61)
More than 30 kg/m²	30 (9.74)
Cervical position	
Central	272 (88.31)
Decentralized	10 (3.25)
Severely deviated	26 (8.44)
External os	
Dilated/parous	11 (3.57)
Normal	268 (87.01)
Pinpoint	29 (9.42)
Visibility	
Straight	270 (87.66)
Tortuous/not visible	38 (12.34)
Obstetric history	
Vaginal delivery	25 (8.12)
Nulliparous	247 (80.19)
C/S without vaginal delivery	36 (11.69)
Cervical procedure	
None	307 (99.68)
Leep	1 (0.32)

Table 3. Comparison of Screening Parameters Between Easy and Difficult Embryo Transfer Groups

Variable	Easy Transfer, n (%)	Difficult Transfer, n (%)	*P* value*
Body mass index			
Less than 25 kg/m²	135 (86.54)	21 (13.46)	0.285
25-29.9 kg/m²	107 (87.70)	15 (12.30)	
More than 30 kg/m²	23 (76.67)	7 (23.23)	
Cervical position			
Central	249 (91.54)	23 (8.46)	<0.001
Decentralized	6 (60.0)	4 (40.0)	
Severely deviated	10 (38.46)	16 (61.54)	
External os			
Dilated/parous	11 (100)	0 (0)	<0.001
Normal	245 (91.42)	23 (8.58)	
Pinpoint	9 (31.03)	20 (68.67)	
Visibility			
Straight	265 (98.15)	5 (1.85)	<0.001
Tortuous/not visible	0 (0)	38 (100)	
Obstetric history			
Vaginal delivery	23 (92.00)	2 (8.00)	0.002
Nulliparous	218 (88.26)	29 (11.74)	
C/S without vaginal delivery	24 (66.67)	12 (33.33)	
Cervical procedure			
None	264 (85.99)	43 (14.01)	0.687
Leep	1 (100)	0 (0)	
Number of transfers			
First	203 (85.29)	35 (14.17)	0.487
Second and more	62 (88.57)	8 (11.43)	

*The chi-square test.

Table 4. Evaluation of the Association Between Obstetric Demographic Variables and Screening Parameters in Easy Versus Difficult Embryo Transfer Groups

Variable	OR	95% CI	*P* value*
Body mass index			
Less than 25 kg/m²	Reference		
25-29.9 kg/m²	0.901	0.443 – 1.832	0.774
More than 30 kg/m²	1.956	0.746 – 5.124	0.172
Cervical position			
Central	Reference		
Decentralized	7.217	1.898 – 27.434	0.004
Severely deviated	17.321	7.055 – 42.526	<0.001
External os			
Dilated/parous	Reference		
Normal	0.042	0.017 – 0.103	<0.001
Pinpoint	1	-	-
Obstetric history			
Vaginal delivery	Reference		
Nulliparous	1.529	0.342 – 6.828	0.578
C/S without vaginal delivery	5.75	1.158 – 28.550	0.032
Total score	11.292	5.355 – 23.810	<0.001
Number of transfers			
First	Reference		
Second and more	0.748	0.239 – 1.697	0.488
Age (y)	0.966	0.913 – 1.023	0.249
Number of pregnancies	0.846	0.558 – 1.282	**0.431**
Cervical length	2.044	1.663 – 2.514	<0.001
Number of deliveries	1.478	0.819 – 2.666	**0.194**
Number of miscarriages	0.414	0.175 – 0.977	**0.044**

OR: Odds ratio, CI: Confidence interval.
* Logistic regression.

Table 5. Diagnostic Performance of the Screening System for Identifying Difficult Embryo Transfer

	Sensitivity (%)	Specificity (%)	Positive predictive value (%)	Negative predictive value (%)	Accuracy (%)
Total screening score≥5	88.4	96.2	79.2	98.1	95.1
Restricted screening score≥3	97.7	96.6	82.4	99.6	96.8
Expanded screening score≥3	65.1	98.5	87.5	94.6	93.8
Cervical ultrasound score≥2	100	100	100	100	100

PPV: Positive predictive value, NPV: Negative predictive value.

each 1-mm increase in cervical length was associated with approximately twofold higher odds of difficult transfer. Among participants with a history of miscarriage, each additional miscarriage was associated with approximately 59% lower odds of difficult embryo transfer. In addition, each one-unit increase in the total ART-ET score was associated with approximately 11-fold higher odds of difficult embryo transfer.

Table 5 presents the diagnostic performance of the ART-ET scoring systems for identifying difficult embryo transfer, including sensitivity, specificity, positive predictive value, negative predictive value, and overall diagnostic accuracy.

The diagnostic performance of the screening systems at the selected cut-off values is presented in Table 5. The cut-off values were ≥5 for the Total screening score, ≥3 for the Restricted screening score, ≥3 for the Expanded screening score, and ≥2 for the Cervical ultrasound score. For the Total screening score at a cut-off of ≥5, sensitivity was 88.4%, specificity was 96.2%, positive predictive value was 79.2%, negative predictive value was 98.1%, and overall accuracy was 95.1%. The corresponding diagnostic performance measures for the other screening systems are also presented in Table 5.

Figure 1 presents the receiver operating characteristic (ROC) curve for the total ART-ET score. The AUC was 0.98, indicating excellent discrimination between difficult and easy embryo transfers. The ROC analysis provided further information on the discriminatory performance of the total ART-ET score across different cut-off values.

Discussion

In the present study, out of a total of 308 embryo transfers, 43 cases (13.96%) were classified as difficult transfers, while 265 cases (86.04%) were classified as easy transfers. This incidence is consistent with findings from a study conducted in Dubai, where among 239 patients, 8.8% of transfers were reported as difficult and 91.2% as easy (19). This concordance may indicate a relatively stable prevalence of difficult embryo transfers across different populations.

In the assessment of the screening tool parameters, only cervical position, external cervical os morphology, ultrasonographic appearance of the cervical canal, obstetric history, and cervical length showed a significant association with difficult transfer ($P < 0.05$). In the difficult transfer group, severe cervical deviation, pinhole-like external os, tortuous cervical canal, and increased cervical length were more prevalent. These findings are in line with the results reported by Ata et al; in their study, although BMI and external os appearance did not differ significantly between groups, severe cervical deviation, tortuosity of the cervical canal, and a history of cesarean section without vaginal delivery were more common in difficult transfers (19).

Previous studies have suggested that when difficult embryo transfer is anticipated, appropriate procedural strategies, such as the use of a stiffer catheter, obturator,

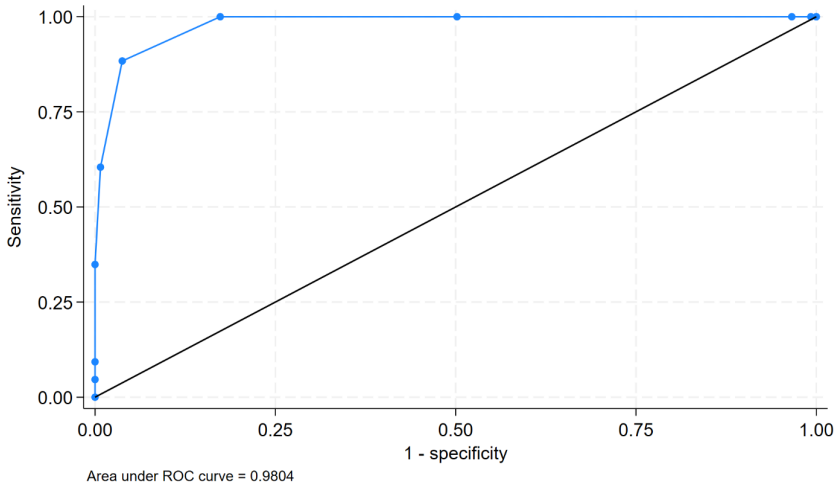

Figure 1. ROC Curve for the Total ART-ET Score.

tenaculum, or performance of the procedure by a more experienced physician, may facilitate embryo transfer and may be associated with improved reproductive outcomes (20). However, the present study did not assess pregnancy outcomes following difficult embryo transfer or modified transfer techniques. Larger multicenter studies involving different infertility centers are warranted to investigate further the association between difficult embryo transfer and pregnancy outcomes.

In the study by Larue et al, conducted on 306 IVF participants, 155 cases experienced varying degrees of difficult transfer, of which 55 were classified as "very difficult." The most common anatomical abnormalities associated with difficulty included abnormal cervical crypts and tortuosity of the cervical canal, whereas internal os contraction and severe uterine anteversion were less frequent (22). These findings underscore the critical role of precise cervical anatomical assessment prior to embryo transfer.

Embryo transfer is recognized as one of the most critical clinical steps in the IVF cycle, and numerous studies have shown that difficulty during this stage is associated with reduced pregnancy rates. Understanding the anatomical causes of difficult transfer can lead to major modifications in transfer techniques and the development of more adaptable catheters (19,20,22) .Considering the limited number of studies in this area and the lack of a standardized tool applicable across all centers, further research with larger sample sizes is needed to evaluate anatomical features and the parameters examined in the present study. This would help establish a unified approach for identifying difficult transfers.

Mechanistically, difficult embryo transfer may negatively affect treatment outcomes through traumatic embryo deposition, induction of uterine contractions, and embryo displacement after placement, or improper positioning within the uterine cavity. The aim of many studies has been to convert difficult transfers into easy ones through technique modification or preventive preparation (18).

In the study by Aboujaoudé in Lebanon, the combination of the endocervical canal pathway and the uterine–cervical angle was introduced as a novel ultrasonography index for predicting difficult embryo transfer. A tortuous canal combined with an angle greater than 90 degrees was associated with the highest utilization of a stiff catheter and difficult transfer (23). These results suggest that pre-transfer ultrasonography assessment can serve as an effective tool for anticipating technical difficulties.

In the univariate logistic regression analysis of the present study, cervical position, external cervical os morphology, obstetric history, cervical length, and number of miscarriages were significantly associated with difficult transfer. The likelihood of difficult transfer was approximately 7-fold higher in individuals with a non-central cervix and increased to approximately 17-fold in cases with severe deviation. A history of cesarean section without vaginal delivery was associated with a 5.75-fold higher likelihood of difficult transfer compared with vaginal delivery. Additionally, each millimeter increase in cervical length was associated with approximately twofold higher odds of difficult transfer, whereas an increased number of miscarriages was associated with lower odds of difficult transfer. These findings describe the associations of individual demographic, obstetric, and cervical characteristics with difficult embryo transfer.

Separately, the prespecified ART-ET total score, which was constructed from the screening tool components, was evaluated as a composite screening score. The strong association observed between the total score and difficult transfer should be interpreted as an assessment of the composite screening system rather than as an independent effect beyond its individual components. Because the total score incorporates several of the variables that were individually associated with difficult transfer, the association between the total score and the outcome is expected to reflect the combined contribution of these components.

The diagnostic performance of the prespecified ART-ET composite score, with an overall accuracy of 95.1%, sensitivity of 88.4%, specificity of 96.2%, positive predictive value of 79.2%, and negative predictive value of 98.1%, indicates a high level of discrimination between difficult and easy transfers in the present study population. These measures describe the performance of the composite screening score and should not be interpreted as independent effects of the individual score components. Similarly, in the study by Ata et al, a screening tool based on cervical position, cervical canal visibility and length, and obstetric history showed acceptable diagnostic performance for identifying difficult transfer (19), which is broadly consistent with the findings of the present study. These findings suggest that a structured pre-transfer assessment may help identify patients at increased likelihood of technical difficulty and facilitate appropriate procedural planning.

These findings suggest that pre-transfer use of such a screening tool may help identify patients who are more likely to experience technical difficulty during embryo transfer and may support appropriate procedural planning. However, whether use of the tool or subsequent modification of the transfer strategy improves reproductive outcomes requires evaluation in future prospective interventional studies.

A review study in this field reported that the most common cause of difficult embryo transfer is cervical stenosis, and cervical dilation, particularly using Hagar dilators at least three weeks prior to transfer, can be effective in managing such cases (18). However, another review emphasized that, to date, there is no standardized or uniform classification or grading system for defining difficult transfer in the literature, and developing a consensus guideline for diagnosis and intervention in this

area is essential (24). Considering the limited number of studies and the lack of a standardized tool applicable across all centers, multicenter studies with large sample sizes are recommended to validate anatomical parameters and screening scores. Early identification of patients at increased likelihood of difficult transfer may facilitate appropriate procedural planning, including consideration of mock transfer, selected use of anesthesia, or referral to a more experienced operator. However, the present study did not assess whether these interventions subsequently improve reproductive outcomes.

Strengths and Limitations of the study

One strength of this study is the evaluation of a noninvasive approach for estimating the likelihood of difficult embryo transfer before the procedure. The proposed scoring system incorporates cervical anatomical characteristics and transvaginal ultrasound findings and provides a quantitative estimate of the risk of difficult transfer. This approach may offer a practical means of preprocedural assessment, although its clinical utility should be further evaluated in prospective studies.

The observed diagnostic performance of the prespecified composite screening score in the present study suggests that this tool may have potential for identifying patients at increased likelihood of difficult embryo transfer before the procedure. This information may potentially support procedural planning, including consideration of an appropriate transfer technique or a more experienced operator when necessary. However, given the single-center design, the relatively limited number of difficult-transfer events, and the absence of external validation, these findings should be interpreted cautiously. Further multicenter studies and external validation are needed to determine the generalizability and clinical applicability of the proposed screening tool.

Another limitation of the present study is that both fresh and frozen embryo transfers were included, but transfer type was not separately evaluated in the statistical analysis. Future prospective studies should evaluate fresh and frozen transfers separately and determine whether transfer type contributes independently to difficult embryo transfer.

Conclusions

The findings of this study indicated that certain cervical anatomical features, including severe cervical deviation, a "pinpoint" appearance of the external os, cervical canal tortuosity on ultrasonography, and a history of cesarean section without previous vaginal delivery, were significantly associated with an increased likelihood of difficult embryo transfer. The prespecified ART-ET composite screening tool also demonstrated good diagnostic performance in distinguishing difficult from easy transfers in the study population. Given the potential clinical relevance of difficult embryo transfer, pre-transfer clinical and ultrasonographic assessment may aid in identifying patients at increased likelihood of technical difficulty and support appropriate procedural planning. However, the present study did not evaluate clinical pregnancy, implantation, ongoing pregnancy, miscarriage, or live-birth outcomes. Larger prospective and validation studies are recommended to validate the screening tool and to determine whether its use, or subsequent targeted interventions, can improve reproductive outcomes.

Authors' Contribution

Conceptualization: Ayda Najafian, Tayebeh Rashidian, Ashraf Aleyassin, Marzieh Aghahosseini, Sedigheh Hoseinimousa, Nasibeh Sharifi, Hojjat Sayyadi.
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Project administration: Tayebeh Rashidian.
Supervision: Ayda Najafian.
Validation: Sedigheh Hoseinimousa, Nasibeh Sharifi.
Writing–original draft: All authors.
Writing–review & editing: All authors.

Conflict of Interests

Authors declare that they have no conflict of interests.

Declaration of generative AI and AI-assisted technologies in the writing process

Artificial intelligence-based tools, including ChatGPT and Grammarly, were used exclusively for English language editing and proofreading during manuscript preparation. These tools had no role in study design, data analysis, data interpretation, or scientific decision-making. The authors take full responsibility for the content of the manuscript.

Data Availability Statement

The data collected for this study are available upon reasonable request to the corresponding author.

Ethical Issues

This study was approved by the Ethics Committee of Tehran University of Medical Sciences, Tehran, Iran. (Code: IR.TUMS.SHARIATI.REC.1404.047). Sample collection commenced after obtaining written informed consent from the study participants. All principles of the Declaration of Helsinki were followed, including those concerning the confidentiality and secure handling of patient information.

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