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ORIGINAL

Fertility Outcomes and Embryo Development in Assisted Reproductive Technology: Conventional vs. Mechanical ICSI

Resultados de fertilidad y desarrollo embrionario en tecnología de reproducción asistida: ICSI convencional versus mecánica

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ABSTRACT

Introduction: assisted Reproductive Technology has transformed fertility treatment with new methods such as Intracytoplasmic Sperm Injection (ICSI), coming up with innovative ways to improve male fertility. The following paper compares the two ICSI techniques, which are mechanical and conventional, on matters of efficiency in terms of fertilization. To check for fertilization, an established morphological criterion was used.
Method: this study was conducted at a fertility clinic in Bocah, Indonesia, and utilizes a cross-sectional retrospective methodology. The study analyzes four hundred and fifty-eight oocytes from twenty-four patients while focusing on days one, three, and five of fertilization to check for their success.
Results: results reveal that mechanical ICSI does better than conventional ICSI in producing high-quality embryos after fertilization. Mechanical ICSI demonstrated higher precision, reduced oocyte trauma, and improved fertilization rates (68,8 % vs. 59,3 % on Day 1). The short span of this study means that the success of these methods in facilitating the carrying of long-term pregnancy is not evaluated. It is, however, valuable to note that the study found that despite the efficiency of mechanical ICSI, there are qualms about moving towards large-scale application in fertility clinics due to the high costs involved.
Conclusions: this study examined conventional and mechanical ICSI in assisted reproduction including 30 individuals (mean age: 33,37 years). Mechanical ICSI yielded markedly superior-quality embryos on Days 1, 3, and 5. It enhanced embryo preservation and fertilization results, underscoring its potential as a superior strategy for improving embryo quality and fertility success.

Keywords: Fertilization; Intracytoplasmic Sperm Injection; Embryo; Reproductive Health.

RESUMEN

Introducción: la tecnología de reproducción asistida ha transformado el tratamiento de la fertilidad con nuevos métodos como la inyección intracitoplasmática de espermatozoides (ICSI), que han permitido encontrar formas innovadoras de mejorar la fertilidad masculina. El siguiente artículo compara las dos técnicas de ICSI, mecánica y convencional, en cuanto a la eficiencia en términos de fertilización. Para comprobar la fertilización, se utilizó un criterio morfológico establecido.
Método: este estudio se llevó a cabo en una clínica de fertilidad en Bocah, Indonesia, y utiliza una metodología retrospectiva transversal. El estudio analiza cuatrocientos cincuenta y ocho ovocitos de veinticuatro pacientes, centrándose en los días uno, tres y cinco de la fertilización para comprobar su éxito.
Resultados: los resultados revelan que la ICSI mecánica es mejor que la ICSI convencional en la producción de embriones de alta calidad después de la fertilización. La ICSI mecánica demostró una mayor precisión,

redujo el traumatismo de los ovocitos y mejoró las tasas de fertilización (68,8 % frente al 59,3 % en el día 1). El breve período de este estudio significa que no se ha evaluado el éxito de estos métodos para facilitar la gestación a largo plazo. Sin embargo, es valioso señalar que el estudio encontró que, a pesar de la eficiencia de la ICSI mecánica, existen dudas sobre avanzar hacia una aplicación a gran escala en las clínicas de fertilidad debido a los altos costos involucrados.

Conclusiones: este estudio examinó la ICSI convencional y mecánica en reproducción asistida que incluyó a 30 personas (edad media: 33,37 años). La ICSI mecánica produjo embriones de calidad notablemente superior en los días 1, 3 y 5. Mejoró la preservación del embrión y los resultados de fertilización, lo que subraya su potencial como una estrategia superior para mejorar la calidad del embrión y el éxito de la fertilidad.

Palabras clave: Fertilización; Inyección Intracitoplasmática de Espermatozoides; Embrión; Salud Reproductiva.

INTRODUCTION

Assisted Reproductive Technology (ART) is a technology used to achieve pregnancy through specific procedures for individuals experiencing infertility. ART services are efforts to obtain pregnancy outside of natural means without the process of sexual intercourse. ART has provided new hope for couples facing infertility issues.[1] Various types of ART that can be utilized include intrauterine insemination (IUI), in vitro fertilization (IVF), Intracytoplasmic Sperm Injection (ICSI), and cryopreservation of gametes or embryos.[1] ICSI is a technique in ART that is used in cases where there is male infertility that could be caused by a wide range of issues that include a low sperm count or poor quality of the sperm. The mechanism of this method is that a single spermatozoon is injected into the oocyte's cytoplasm. This technique prepares gametes to create embryos that can be transferred into the mother's uterus. ICSI has dramatically improved the fertilization rate in previously infertile males and increased the success rate of IVF.[2] There are two types of ICSI, and these are the mechanical and conventional methods. The traditional method is manual, where an embryologist inserts the spermatozoon into the oocyte using a micro-manipulator under the observation of a microscope.[3] The mechanical process is arguably more precise and reduces the incidence of human error.

METHOD

This research had received approval from the Health Research Ethics Committee, Faculty of Medicine of Universitas Indonesia No.KET-1182/UN2.F1/ETIK/PPM.00.02/2024 dated 12 August 2024. This study followed all ethical stipulations starting from the gathering of participants, whereby they were well informed about the intentions of the research and the date it needed for them. The patient data was, therefore, only taken from the medical records with the approval of the patients. This ensured that there was informed consent. The study also met all the parameters of ethical research as it was approved for the procedure by the hospital board; patient confidentiality was upheld in the data collection and analysis process as no patient data was disclosed.

This study evaluates the efficacy of traditional compared to mechanical ICSI techniques using an analysis of medical data from a reproductive clinic in Indonesia. The study examines treatments conducted from April to October 2024, encompassing 458 eggs obtained from 29 couples who underwent both ICSI techniques. The main objective is to evaluate the efficacy of various approaches in generating high-quality embryos.

Participants in the study must have had In Vitro Fertilization (IVF) using Intracytoplasmic Sperm Injection (ICSI) between 2021 and 2024, utilizing both conventional and mechanical ICSI techniques. Exclusion criteria include patients with fewer than six retrieved eggs, fewer than four mature eggs, the utilization of frozen eggs, significant sperm abnormalities (e.g., low count or poor motility), or sperm obtained directly using PESA (Percutaneous Epididymal Sperm Aspiration) or TESA (Testicular Sperm Aspiration).

The number of participants was calculated based on the success rates of good and poor-quality embryos as follows;

$$n_1 = n_2 = \left(\frac{Z_{\text{Œ}\pm}\sqrt{2PQ} + Z_{\text{Œ}=}\sqrt{P_1Q_1 + P_2Q_2}}{P_1 - P_2} \right)^2$$

n1 = the number of subjects in the conventional ICSI group
n2 = the number of subjects in the mechanical ICSI group
Zα = the standard alpha value of 5 % for a two-tailed hypothesis, which is 1,
Zβ = the standard beta value of 20 %, which is 0,84
P1 = the proportion of good-quality embryo outcomes = 0,72
Q1 = 1 - P1=0,28

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P2 = the proportion of poor-quality embryo outcomes = 0,74
Q2 = 1 - P2=0,26
P1 - P2 = the minimal difference in embryo outcomes considered significant, set at 45 %
P = (P1 – P2)/2=0,73
Q = 1-P = 0,27
Using these calculations, the minimum sample size is 24

$$n_1 = n_2 = \left(\frac{1{,}64\sqrt{2(0{,}73)(0{,}27)} + 0{,}84\sqrt{(0{,}72)(0{,}28) + (0{,}74)(0{,}26)}}{0{,}45} \right)^2 = 24{,}25$$

Medical records available at the Bocah Indonesia Clinic in Tangerang and Jakarta were used for data collection. This data included images and morphological records of embryos produced from conventional and mechanical ICSI. The research flow can be seen in Figure 1. Embryo morphology analysis was carried out by embryology experts using established morphological criteria.[19,20,21,22] A comparison between the two groups of embryos was performed to determine significant differences in morphology.[21,22] Statistical analysis was performed using the SPSS version 22 software. The data were tested using the chi-square test to determine the existence of relationships between variables. A confidence level of 95 % (P < 0,05) was used to determine statistical significance.

RESULTS

The objective of this study is to compare the fertilization outcomes of conventional and mechanical ICSI as a form of assisted reproductive technology. A total of 30 patients participated in the study, with an age range of 24 to 44 years and an average age of 33,37 years. Two hundred fifty-three oocytes were fertilized using conventional ICSI, and 205 oocytes were fertilized using mechanical ICSI. The results of the comparative analysis of embryo morphology on Day 1, Day 3, and Day 5 for both ICSI techniques are as follows:

Table 1. Results of the comparative analysis of embryo morphology

Technique		Fertilization Result					
		Day 1		Day 3		Day 5	
		Good	Not Good	Good	Not Good	Good	Not Good
Mechanical (n=205)	ICSI	141 (68,8 %)	64 (31,2 %)	125 (61,0 %)	80 (39,0 %)	80 (39,0 %)	125 (61,0 %)
Conventional (n=253)	ICSI	150 (59,3 %)	103 (40,7 %)	115 (45,5 %)	138 (54,5 %)	60 (23,7 %)	193 (76,3 %)
Total		291 (63,5 %)	167 (36,5 %)	240 (52,4 %)	218 (47,6 %)	140 (30,6 %)	318 (69,4 %)
p-Value		0,036		0,001		0,000	

Day 1: The mechanical ICSI technique resulted in 141 out of 205 good-quality oocytes (68,8 %), while the conventional ICSI technique produced 141 out of 253 good-quality oocytes (59,3 %). The difference in fertilization outcomes between the two methods was (p=0,036). Day 3: Mechanical ICSI yielded 125 out of 205 good-quality oocytes (61,0 %), whereas conventional ICSI resulted in 138 out of 253 poor-quality oocytes (54,5 %). The difference in outcomes was (p=0,001).[23] Day 5: The mechanical ICSI technique produced 125 out of 205 poor-quality oocytes (61,0 %); the conventional ICSI technique resulted in 193 out of 253 poor-quality oocytes (76,3 %). However, the number of poor-quality oocytes was higher with the traditional ICSI technique, and a significant difference was found (p=0,000).[23]

The Conventional and Mechanical ICSI methods can be viewed in Video 1 and Video 2 in the supplementary files.

In the case of ART, the choice of the method used for fertilization plays a crucial role in determining the success rate of other methods, such as IVF. Most cases of male infertility are predominantly dealt with using ICSI, with the mechanical way showing more potential for success due to the reduction of human error.[4] While widespread research is speaking about using ICSI, there are limitations in comparing the success rates between conventional and mechanical techniques. Studies suggest that mechanical ICSI has more benefits due to its accuracy and reproducibility, which increases the outcomes of fertilization.[5] However, there is the argument that the costs and complexity of implementing mechanical ICSI do not justify the benefits of the conventional ways. As the need to optimize ART procedures to increase fertilization success rates is urgent, it is necessary to conduct a comparative analysis of mechanical and conventional ICSI to establish the most efficient.

Experts in fertility treatments say that when sperm problems cause infertility, ICSI is usually the best option.[4,6,7] In the standard ICSI method, an embryologist uses a microscope to inject one sperm into an egg.[5,8] This process depends a lot on the skill of the person doing it, which can sometimes affect the quality of the embryo and how successful the fertilization is. Even so, this method has helped improve fertilization rates and sometimes leads to the carrying of long-term pregnancies.[8,9,10] To make things better, a newer approach called mechanical ICSI was developed. The most similar type with the new mechanical ICSI methods in this research is PIEZO-ICSI, which uses controlled pressure to inject the sperm into the egg.[11,12] This method reduces the chances of damaging the sperm or egg and is especially helpful when sperm quality is poor and less likely to fertilize.[13] PIEZO-ICSI has 70–80 % fertilization success rates, compared to 60–70 % with the traditional method.[14,15] However, there are downsides to PIEZO-ICSI. It's more expensive and more complicated to perform, and it doesn't necessarily lead to more pregnancies or higher chances of having a baby.[16,17] Other factors, like genetic problems with the sperm (such as DNA damage or gene mutations), also affect whether ICSI will work. More research is needed to figure out which method is genuinely better.[18]

The results of this study indicate that the mechanical ICSI technique provides better fertilization outcomes in the early stages and maintains higher embryo quality up to Day 5 compared to the conventional ICSI technique.[24,25,26] The significant differences at each stage highlight the potential superiority of the mechanical ICSI technique in assisted reproductive technology, particularly in the context of fertilization and embryo development.[27,28,29] The appropriate ART selection for patients can be seen in Figure 2, which shows the ART options that can be chosen based on the needs and indications of infertility patients. If ICSI is recommended for a patient, a physician can choose between two ICSI options: conventional ICSI and mechanical ICSI. Mechanical ICSI is a newer ICSI technique that is relatively faster and causes less traumatic damage to oocytes compared to the traditional method.

Some limitations of this study include that the research was carried out in one center, which made the test parameters low. The inability to include a set of participants from a wide range of demographics limits the reproducibility of this study and its applications in more diverse settings, which may have different clinical protocols. In addition, the retrospective design as the primary method had limitations in that it could not provide more controlled comparisons or prevent biases that come with this design. Future studies can improve on these findings and conduct research across various fertility centers to ensure that the findings are generalizable. They could also explore the long-term impacts of these methods by increasing the period and checking on the birth rates as a result of both methods to establish a conclusive evaluation.

CONCLUSION

This research analyzed the efficacy of conventional versus mechanical intracytoplasmic sperm injection (ICSI) methods in assisted reproductive technology. Thirty patients, aged 24 to 44 years (mean age: 33,37 years), participated in the study, resulting in 253 oocytes fertilized via conventional ICSI and 205 via mechanical ICSI. Embryo morphology was assessed on Day 1, Day 3, and Day 5, indicating notable differences between the two methods.

On Day 1, mechanical ICSI resulted in 68,8 % good-quality oocytes (141/205), surpassing conventional ICSI, which achieved 59,3 % (150/253). The difference was statistically significant (p = 0,036). On Day 3, mechanical ICSI demonstrated superior outcomes, yielding 61,0 % good-quality embryos, in contrast to 45,5 % for conventional ICSI (p=0,001). On Day 5, mechanical ICSI exhibited enhanced embryo preservation, showing 61,0 % poor-quality embryos in contrast to 76,3 % in the conventional group. The observed difference, accompanied by a highly significant p-value (p=0,000), highlights the effectiveness of mechanical ICSI in preserving embryo quality.

Mechanical ICSI consistently yielded superior fertilization outcomes, characterized by increased proportions of high-quality oocytes and embryos. The findings indicate its potential as a more effective method in assisted reproductive technology, facilitating enhanced embryo development and improving the likelihood of successful fertility treatment.

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DATA AVAILABILITY

The conventional and Mechanical ICSI Method would be availeble in supplementary files.

COMPETING INTERESTS

No competing interest are associated with this article.

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