Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Pregnancy and Perinatal Outcomes Following Radiofrequency Ablation in Monochorionic Twin Pregnancies: A Comparative Study of MCMA and MCDA Gestations

Fatemeh Rahimi Sharbaf
Tehran Univercity of Medical Science, Iran
Maryam Tat
Tehran Univercity of Medical Science, Iran
Mahboobeh Shirazi
Tehran Univercity of Medical Science, Iran
Maedeh Mollaalipour amiri
alipoormaedeh67@gmail.com
Tehran Univercity of Medical Science, Iran
Behrokh Sahebdel
Tehran Univercity of Medical Science, Iran
Fatemeh Golshahi
Tehran Univercity of Medical Science, Iran
Nafiseh Saedi
Tehran Univercity of Medical Science, Iran

Research Article

Keywords: Radiofrequency ablation, Selective fetal reduction, Monochorionic twins, Monochorionic monoamniotic pregnancy, Monochorionic diamniotic pregnancy, Live birth

Posted Date: September 10th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10558761/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Monochorionic twin pregnancies are associated with an increased risk of advers fetal and perinatal outcome. Radiofrequency ablation (RFA) is used for selective fetal reduction in complicated monochorionic pregnancies. This study compared pregnancy and neonatal outcomes following RFA between monochorionic monoamniotic (MCMA) and monochorionic diamniotic (MCDA) pregnancies.

Methods

This retrospective comparative cohort study included 130 complicated monochorionic twin pregnancies that underwent selective fetal reduction using RFA at a tertiary fetal medicine center in Tehran, Iran. The study included 43 MCMA and 87 MCDA pregnancies. Miscarriage was defined as pregnancy loss before 24 completed weeks, and intrauterine fetal demise (IUFD) was defined as death of the surviving co-twin at 24 completed weeks or later. Modified Poisson regression with robust variance was used for common binary outcomes, and Firth penalized logistic regression was used for sparse outcomes. Primary models were adjusted for maternal age, gestational age at RFA, and RFA indication. Secondary conditional analyses evaluated live birth and preterm prelabor rupture of membranes (PPROM) after excluding pregnancies ending in miscarriage.

Results

In the overall treated cohort, among pregnancy that progressed beyond the miscarriage period the live birth was 24 of 29 MCMA pregnancies (82.7%) and 69 of 70 MCDA pregnancies (98.5%). IUFD of the surviving co-twin occurred in 17.2% of MCMA pregnancies and 1.1% of MCDA pregnancies (adjusted odds ratio, 7.184; 95% CI, 1.063–83.300; p = 0.043). PPROM occurred in 13.8% and 35.7% of MCMA and MCDA pregnancies, respectively, although the adjusted association was not statistically significant (adjusted RR, 0.404; 95% CI, 0.146–1.121; p = 0.082). Among pregnancies resulting in live birth, no statistically significant differences were observed in gestational age at delivery, birth weight, Apgar scores, preterm birth, neonatal intensive care unit admission, small for gestational age, respiratory distress syndrome, or neonatal death.

Conclusion

Radiofrequency ablation (RFA) achieved acceptable perinatal outcomes in selected complicated monochorionic monoamniotic (MCMA) pregnancies and appears to be a clinically feasible option for selective fetal reduction in this high risk population. Among pregnancies resulting in live birth

,gestational age at delivery, birth weight and short term neonatal outcome were generaly comparable between MCMA and MCDA pregnancies

Background

High-risk pregnancies remain a major challenge in maternal and fetal medicine owing to a significant increase in risk of adverse maternal and perinatal outcomes and require specialized and multidisciplinary care [1–4]. Notably, Multiple gestation is associated with a significant increase in maternal and neonatal morbidity and mortality compared with singleton pregnancies [1, 2, 5]. Over the past few decades, the prevalence of these pregnancies has increased significantly, which is mainly attributed to the expansion of assisted reproductive technologies and the advanced maternal age [1, 2, 4–6]. This trend highlights the importance of specialized prenatal care.

Twin pregnancy is the most common type of multiple pregnancy and contributes substantially to the overall burden of perinatal mortality and morbidity [7–9]. Overall, such pregnancies are associated with an increased risk of miscarriage, preterm birth, fetal abnormalities, and maternal complications such as blood pressure disorders and gestational diabetes [1, 5]. Accordingly, Twin pregnancies are classified as dichorionic or monochorionic, which are characterized by a shared placenta, and further divided into monochorionic-diamniotic (MCDA) and monochorionic-monoamniotic (MCMA) types, depending on whether the fetuses have separate or a single amniotic sac, and are associated with a higher clinical risk [3, 5, 10]. Placental vascular anastomoses create direct hemodynamic connections between fetuses [3, 4, 10]. Consequently, these pregnancies have higher rates of fetal death, perinatal morbidity, and neurodevelopmental impairment than dichorionic twins [3–5, 10].

Although MCMA is rare, it carries a higher risk due to cord entanglement and is associated with significantly lower survival rates [11, 12]. Key complications specific to monochorionic pregnancies include twin-to-twin transfusion syndrome (TTTS), selective fetal growth restriction (sFGR), twin anemia–polycythemia sequence (TAPS), and TRAP sequence [3, 5, 6, 13, 14]. These complications mainly arise from an imbalance in blood flow through the placental anastomoses and can lead to significant hemodynamic instability, cardiac dysfunction, and potentially fetal demise [6, 10]. Furthermore, in the event of single fetal death, the surviving co-twin remains at high risk of neurological injury or death, with neurodevelopmental impairment reported in up to 26% of cases [3, 4]. In such complex conditions, selective fetal reduction may be considered, particularly in severe TTTS, advanced sFGR, TRAP sequence, or major fetal anomalies, to improve survival and protect the remaining fetus [2, 3, 15, 16]. However, due to shared placental circulation, conventional intracardiac injection of lethal agents is contraindicated [4, 10].

Accordingly, several techniques have been developed to interrupt blood flow to the affected fetus, including fetoscopic laser coagulation, bipolar cord occlusion, and other ablative approaches [2, 4, 16]. Of these, radiofrequency ablation (RFA) has emerged as a widely adopted minimally invasive modality, with a favorable safety profile and procedural reliability [6]. By generating localized thermal necrosis

within the umbilical cord vessels or targeted fetal tissue, RFA achieves effective vascular occlusion while minimizing hemodynamic exchange between fetuses [6]. Its technical simplicity, reproducibility, and lower risk of membrane injury or premature rupture of the amniotic sac have contributed to its growing clinical acceptance [6, 16].

Despite these advances, its outcomes remain influenced by several key factors, including chorionicity (MCMA vs. MCDA), gestational age at intervention, and the underlying indication for the procedure [2, 4, 16]. Adverse events such as preterm birth, PPROM, and neonatal complications continue to pose significant challenges [2, 16]. Moreover, the current evidence on RFA outcomes, especially in comparative analyses between different subtypes, remains limited and heterogeneous [17, 18].

Monochorinic monoamniotic (MCMA) pregnancies carry a significantly greater risk of advers fetal outcoms than monochorionic diamniotic (MCDA) pregnancies, largly because of the increased risk of umblical cord entanglement.[19]

For selective fetal reduction in complicated monochorionic monoamniotic (MCMA) pregnancies, bipolar cord coagulation has been reported as one of the established vaso-occlusive techniques in the published literature.

While bipolar cord coagulation has been the most commonly reported technique for selective fetal reduction in complicated monochorionic monoamniotic (MCMA) pregnancies, the present study aims to evaluate radiofrequency ablation (RFA) as an alternative vaso-occlusive approach for complicated MCMA pregnancies. RFA can be performed percutaneously under ultrasound guidance without the need for maternal general anestesia and may offer technical simplicity and potential cost advantages. furthermore, perinatal outcomes following RFA in complicated MCMA pregnancies will be compared with those of monochorionic diamniotic (MCDA) pregnancies undergoing the same procedure in Yas hospital compelex.

Materials and Methods

Study Design and Population

This retrospective comparative cohort study included pregnancies complicated by monochorionic twins that underwent selective fetal reduction using radiofrequency ablation (RFA) at Yas Hospital, a tertiary fetal medicine referral center affiliated with Tehran University of Medical Sciences, between 2021 and 2025. All eligible pregnancies available during the study period were included.

Pregnancies were classified as monochorionic monoamniotic (MCMA) or monochorionic diamniotic (MCDA) according to prenatal ultrasonographic findings. The study groups were defined according to amnionicity rather than pregnancy outcome.Data were collected using a standardized data collection form developed specifically for this study. The data collection form is provided as Supplementary File 1.

Eligibility Criteria

Pregnancies were eligible for inclusion if they were classified as MCMA or MCDA, underwent selective fetal reduction using RFA during the study period, and had sufficient clinical information to determine the principal pregnancy outcome.

According to the institutional clinical protocol, RFA was generally performed between 16 weeks and 26 weeks and 6 days of gestation. One clinically justified procedure performed at 28 weeks and 6 days was retained as an investigator-confirmed exception because it met the remaining eligibility criteria.

Pregnancies with threatened miscarriage, cervical dilatation, or preterm prelabor rupture of membranes (PPROM) before RFA were excluded. Records lacking sufficient information to determine miscarriage, intrauterine fetal demise (IUFD), or live-birth status were also excluded.

Indications and Preprocedural Evaluation

Indications for selective fetal reduction included twin–twin transfusion syndrome, selective fetal growth restriction, twin reversed arterial perfusion sequence, and major structural or genetic abnormality affecting one fetus.

Before the procedure, all patients underwent aneuploidy screening, detailed fetal anatomical assessment, and fetal echocardiography. Amniocentesis was performed when clinically indicated because of an increased risk of chromosomal abnormality. Amnioreduction was performed when clinically required in pregnancies complicated by TTTS with polyhydramnios.

RFA Procedure

All procedures were performed by experienced maternal–fetal medicine specialists under continuous ultrasonographic guidance. Local anesthesia was administered with adjunct intramuscular sedation consisting of 25 mg pethidine and 25 mg promethazine. Prophylactic amoxicillin at a dose of 1000 mg was administered approximately 30 minutes before the **procedure.**

A 17-gauge radiofrequency needle was inserted percutaneously through the maternal abdomen and uterine wall and positioned near the abdominal insertion of the umbilical cord of the target fetus. Radiofrequency energy was directed toward the umbilical vessels, preferentially the umbilical vein, with energy applied to achieve a temperature of approximately 100°C for 1–2 minutes. Applications were repeated, typically for two to three cycles, until complete cessation of blood flow was confirmed using Doppler ultrasonography.

Follow-up and Data Collection

Patients were followed after RFA through delivery, and live-born neonates were followed for 28 days after birth. Data were collected using a researcher-designed checklist based on medical records, clinical assessments, and telephone follow-up when necessary.

Maternal and pregnancy-related variables included maternal age, prepregnancy body mass index, gravidity, parity, mode of conception, hypertension, diabetes mellitus, hypothyroidism, gestational age at RFA, indication for RFA, placental abruption, preeclampsia, fever or chorioamnionitis, bleeding, miscarriage, IUFD of the surviving co-twin, fetal growth restriction, preterm labor, PPROM, gestational age at delivery, and mode of delivery.

Neonatal variables included birth weight, Apgar scores at 1 and 5 minutes, neonatal intensive care unit admission, small for gestational age, respiratory distress syndrome, preterm birth, and neonatal death within 28 days after birth.

Outcome Definitions

Miscarriage was defined as any pregnancy loss occurring before 24 completed weeks of gestation.

IUFD was defined as death of the surviving co-twin following RFA at 24 completed weeks of gestation or later. Live birth was defined as delivery of a live-born surviving co-twin

PPROM was defined as rupture of membranes before the onset of labor and before 37 completed weeks of gestation. Preterm labor was defined as labor occurring before 37 completed weeks and resulting in delivery. Preterm birth was evaluated at thresholds of less than 37, 34, and 32 completed weeks.

Fetal growth restriction was defined as an estimated fetal weight below the fifth percentile and/or abnormal fetal Doppler findings. Small for gestational age was defined as birth weight below the 10th percentile .Neonatal death was defined as death within the first 28 days after birth.

Pregnancy outcomes were evaluated in all treated pregnancies. Secondary conditional analyses of live birth and PPROM were performed after excluding pregnancies ending in miscarriage before 24 completed weeks. Mode of delivery and neonatal outcomes were evaluated only among pregnancies resulting in live birth.

Statistical Analysis

Continuous variables were summarized using mean and standard deviation, and categorical variables were presented as frequency and percentage.

Continuous characteristics were compared using Welch’s two-sample t-test. The Mann–Whitney U test was additionally used as a sensitivity analysis. Categorical variables were compared using the chi-square test or Fisher’s exact test, as appropriate

MCDA pregnancies were used as the reference group in all regression models. Modified Poisson regression with a log link and robust sandwich variance estimates was used to estimate risk ratios and 95% confidence intervals for common binary outcomes [21]

Results

A total of 130 pregnancies were included in the study, comprising 43 monochorionic monoamniotic (MCMA) and 87 monochorionic diamniotic (MCDA) pregnancies. Maternal age, prepregnancy body mass index, gravidity, parity, and gestational age at radiofrequency ablation (RFA) did not differ significantly between the groups. The mean gestational age at RFA was 20.55 ± 2.61 weeks in the MCMA group and 20.65 ± 2.39 weeks in the MCDA group ($p = 0.838$).

The distribution of mode of conception differed between the groups. Assisted reproductive technology accounted for 3 of 43 MCMA pregnancies (7.0%) and 19 of 87 MCDA pregnancies (21.8%; $p = 0.045$). RFA indications also differed significantly between the groups ($p < 0.001$). Major fetal anomaly was more frequent in MCMA pregnancies than in MCDA pregnancies (69.8% vs 21.8%), whereas twin–twin transfusion syndrome (14.0% vs 39.1%) and fetal growth restriction (11.6% vs 35.6%) were more frequent in MCDA pregnancies. (Table 1).

Table 1
Baseline maternal, pregnancy, and procedural characteristics

Characteristic	MCMA (n = 43)	MCDA (n = 87)	P value	SMD
Maternal age, years	28.91 (5.24)	30.02 (5.47)	0.263	0.208
Prepregnancy BMI, kg/m²	27.94 (4.70)	27.46 (4.66)	0.581	0.103
Gravidity	1.95 (1.07)	1.99 (1.20)	0.866	0.031
Parity	0.56 (0.80)	0.59 (0.67)	0.843	0.038
Gestational age at RFA, weeks	20.55 (2.61)	20.65 (2.39)	0.838	0.039
Mode of conception and medical history				
Mode of conception			0.045	0.433
Spontaneous conception	40/43 (93.0%)	68/87 (78.2%)		
Assisted reproductive technology	3/43 (7.0%)	19/87 (21.8%)		
Hypertension	2/43 (4.7%)	8/87 (9.2%)	0.495	0.180
Diabetes mellitus	1/43 (2.3%)	7/87 (8.0%)	0.269	0.260
Hypothyroidism	0/43 (0.0%)	7/87 (8.0%)	0.095	0.418
Indication for RFA				
RFA indication			< 0.001	1.097
Twin–twin transfusion syndrome	6/43 (14.0%)	34/87 (39.1%)		
Selective fetal growth restriction	1/43 (2.3%)	2/87 (2.3%)		
Intrauterine growth restriction	5/43 (11.6%)	31/87 (35.6%)		
Twin reversed arterial perfusion sequence	1/43 (2.3%)	1/87 (1.1%)		
Major fetal anomaly	30/43 (69.8%)	19/87 (21.8%)		

After excluding 31 pregnancies that ended in miscarriage before 24 completed weeks, 99 pregnancies remained in the conditional analysis, including 29 MCMA and 70 MCDA pregnancies. Live birth occurred in 24 of 29 MCMA pregnancies (82.8%) and 69 of 70 MCDA pregnancies (98.6%; Fisher's exact p = 0.008). After adjustment for maternal age, gestational age at RFA, and **RFA indication, the probability of**

live birth remained lower in the MCMA group than in the MCDA group (adjusted risk ratio [RR], 0.840; 95% confidence interval [CI], 0.720–0.980; p = 0.027).

In the miscarriage-excluded population, intrauterine fetal demise (IUFD) of the surviving co-twin at 24 completed weeks or later occurred in 5 of 29 MCMA pregnancies (17.2%) and 1 of 70 MCDA pregnancies (1.4%; p = 0.008). Preterm prelabor rupture of membranes (PPROM) occurred in 4 of 29 MCMA pregnancies (13.8%) and 25 of 70 MCDA pregnancies (35.7%; p = 0.031). However, after adjustment for maternal age, gestational age at RFA, and RFA indication, the association between MCMA pregnancy and PPROM was no longer statistically significant (adjusted RR, 0.404; 95% CI, 0.146–1.121; p = 0.082).

Among pregnancies without miscarriage, preterm labor resulting in delivery occurred in 34.5% of MCMA pregnancies and 41.4% of MCDA pregnancies (p = 0.652). No statistically significant between-group differences were observed in placental abruption, preeclampsia, bleeding, or fetal growth restriction. No cases of fever or chorioamnionitis occurred in either group in this conditional population (Table 2, **Panel A).**

Table 2
Pregnancy outcomes according to amnionicity Panel A. Outcomes among pregnancies without miscarriage before 24 completed weeks

Outcome	MCMA (n = 29)	MCDA (n = 70)	P value
Live birth	24/29 (82.8%)	69/70 (98.6%)	0.008
IUFD of the surviving co-twin at ≥ 24 weeks	5/29 (17.2%)	1/70 (1.4%)	0.008
Preterm prelabor rupture of membranes	4/29 (13.8%)	25/70 (35.7%)	0.031
Preterm labor resulting in delivery	10/29 (34.5%)	29/70 (41.4%)	0.652
Placental abruption	2/29 (6.9%)	6/70 (8.6%)	1.000
Preeclampsia	1/29 (3.4%)	4/70 (5.7%)	1.000
Fever or chorioamnionitis	0/29 (0.0%)	0/70 (0.0%)	Not estimable
Bleeding	2/29 (6.9%)	10/70 (14.3%)	0.500
Intrauterine growth restriction	2/29 (6.9%)	0/70 (0.0%)	0.084
Panel B. Outcomes in all treated pregnancies			

In the analysis including all treated pregnancies, miscarriage before 24 completed weeks occurred in 14 of 43 MCMA pregnancies (32.6%) and 17 of 87 MCDA pregnancies (19.5%; p = 0.127). The mean gestational age at miscarriage was 20.20 ± 1.07 weeks in the MCMA group and 20.82 ± 1.42 weeks in the MCDA group. The overall mean gestational age at miscarriage was 20.54 ± 1.30 weeks, and the difference between the groups was not statistically significant (Welch's t-test p = 0.178).

Live birth in the overall treated cohort occurred in 24 of 43 MCMA pregnancies (55.8%) and 69 of 87 MCDA pregnancies (79.3%; p = 0.007). After adjustment for maternal age, gestational age at RFA, and RFA indication, MCMA pregnancy was associated with a lower probability of live birth compared with MCDA pregnancy (adjusted RR, 0.656; 95% CI, 0.495–0.869; p = 0.003).

IUFD of the surviving co-twin at 24 completed weeks or later occurred in 5 of 43 MCMA pregnancies (11.6%) and 1 of 87 MCDA pregnancies (1.1%; p = 0.015). In the adjusted Firth logistic regression model, MCMA pregnancy was associated with higher odds of IUFD than MCDA pregnancy (adjusted odds ratio [OR], 7.184; 95% CI, 1.063–83.300; p = 0.043). The adjusted odds of miscarriage were also higher in the MCMA group, although the association did not reach statistical significance (adjusted OR, 2.380; 95% CI, 0.851–6.972; p = 0.098).

PPROM in the overall treated cohort occurred in 6 of 43 MCMA pregnancies (14.0%) and 34 of 87 MCDA pregnancies (39.1%; p = 0.004). After adjustment, MCMA pregnancy remained associated with a lower risk of PPROM (adjusted RR, 0.366; 95% CI, 0.155–0.862; p = 0.021). Preterm labor resulting in delivery occurred in 25.6% of MCMA pregnancies and 33.3% of MCDA pregnancies (p = 0.423), and the adjusted association was not statistically significant (adjusted RR, 0.669; 95% CI, 0.351–1.277; p = 0.223). No statistically significant differences were identified in placental abruption, preeclampsia, fever or chorioamnionitis, bleeding, or fetal growth restriction in the overall cohort (Table 2, Panel B; Table 4).

Table 4
Adjusted associations of MCMA versus MCDA with pregnancy outcomes

Outcome	MCMA	MCDA	Effect measure	Adjusted estimate (95% CI)	P value
Live birth in all treated pregnancies	24/43 (55.8%)	69/87 (79.3%)	RR	0.656 (0.495–0.869)	0.003
Miscarriage before 24 completed weeks	14/43 (32.6%)	17/87 (19.5%)	OR	2.380 (0.851–6.972)	0.098
IUFD of the surviving co-twin at ≥ 24 weeks	5/43 (11.6%)	1/87 (1.1%)	OR	7.184 (1.063–83.300)	0.043
PPROM in all treated pregnancies	6/43 (14.0%)	34/87 (39.1%)	RR	0.366 (0.155–0.862)	0.021
Preterm labor resulting in delivery	11/43 (25.6%)	29/87 (33.3%)	RR	0.669 (0.351–1.277)	0.223
Live birth after excluding miscarriage	24/29 (82.8%)	69/70 (98.6%)	RR	0.840 (0.720–0.980)	0.027
PPROM after excluding miscarriage	4/29 (13.8%)	25/70 (35.7%)	RR	0.404 (0.146–1.121)	0.082

RR indicates risk ratio; OR, odds ratio; CI, confidence interval; IUFD, intrauterine fetal demise; PPROM, preterm prelabor rupture of membranes; MCMA, monochorionic monoamniotic; MCDA, monochorionic diamniotic

Exploratory descriptive analysis according to RFA indication showed that 4 of the 5 IUFD events in the MCMA group (80.0%) occurred in pregnancies in which major fetal anomaly was the indication for selective reduction, whereas 1 event (20.0%) occurred in a pregnancy complicated by twin–twin transfusion syndrome. Among pregnancies with major fetal anomaly, live birth occurred in 14 of 30 MCMA pregnancies (46.7%) and 17 of 19 MCDA pregnancies (89.5%). Because several indication-by-group categories contained very small numbers, these indication-specific findings were considered descriptive and were not used for formal causal inference.

Among the 93 pregnancies resulting in live birth, cesarean delivery occurred in 18 of 24 MCMA pregnancies (75.0%) and 54 of 69 MCDA pregnancies (78.3%; p = 0.780). The mean gestational age at delivery was 34.49 ± 4.22 weeks in the MCMA group and 34.61 ± 3.93 weeks in the MCDA group (p = 0.898). The mean interval from RFA to delivery was 12.93 ± 6.42 weeks and 13.48 ± 4.98 weeks, respectively (p = 0.706).

The mean birth weight was 2299.6 ± 892.0 g in the MCMA group and 2331.5 ± 741.6 g in the MCDA group (p = 0.876). Mean Apgar scores at 1 minute were 8.58 ± 0.58 and 8.33 ± 1.56, respectively (p = 0.264), and mean Apgar scores at 5 minutes were 9.58 ± 0.58 and 9.33 ± 1.56, respectively (p = 0.264).

No statistically significant between-group differences were identified in neonatal intensive care unit admission (45.8% vs 47.8%; p = 1.000), neonatal death within 28 days (8.3% vs 13.0%; p = 0.722), small for gestational age (20.8% vs 18.8%; p = 1.000), respiratory distress syndrome (4.2% vs 7.2%; p = 1.000), preterm birth before 37 weeks (45.8% vs 56.5%; p = 0.477), preterm birth before 34 weeks (37.5% vs 33.3%; p = 0.804), or preterm birth before 32 weeks (29.2% vs 18.8%; p = 0.387) (Table 3). These delivery and neonatal analyses were restricted to pregnancies resulting in live birth.

Table 3
Delivery and neonatal outcomes among pregnancies resulting in live birth

Outcome	MCMA (n = 24)	MCDA (n = 69)	P value
Mode of delivery			
Vaginal delivery	6/24 (25.0%)	15/69 (21.7%)	0.780
Cesarean delivery	18/24 (75.0%)	54/69 (78.3%)	
Continuous delivery and neonatal outcomes			
Gestational age at delivery, weeks	34.49 (4.22)	34.61 (3.93)	0.898
Interval from RFA to delivery, weeks	12.93 (6.42)	13.48 (4.98)	0.706
Birth weight, g	2299.6 (892.0)	2331.5 (741.6)	0.876
Apgar score at 1 minute	8.58 (0.58)	8.33 (1.56)	0.264
Apgar score at 5 minutes	9.58 (0.58)	9.33 (1.56)	0.264
Binary neonatal outcomes			
NICU admission	11/24 (45.8%)	33/69 (47.8%)	1.000
Neonatal death within 28 days	2/24 (8.3%)	9/69 (13.0%)	0.722
Small for gestational age	5/24 (20.8%)	13/69 (18.8%)	1.000
Respiratory distress syndrome	1/24 (4.2%)	5/69 (7.2%)	1.000
Preterm birth < 37 weeks	11/24 (45.8%)	39/69 (56.5%)	0.477
Preterm birth < 34 weeks	9/24 (37.5%)	23/69 (33.3%)	0.804
Preterm birth < 32 weeks	7/24 (29.2%)	13/69 (18.8%)	0.387

NICU, neonatal intensive care unit; MCMA, monochorionic monoamniotic; MCDA, monochorionic diamniotic.

Discussion

In this retrospective comparative cohort study, pregnancy and neonatal outcomes following selective fetal reduction using radiofrequency ablation were evaluated in 43 monochorionic monoamniotic

(MCMA) and 87 monochorionic diamniotic (MCDA) pregnancies. Among MCMA pregnancies resulting in live birth, the mean gestational age at delivery was 34.49 ± 4.22 weeks, and the mean birth weight was 2299.58 ± 891.98 g.The miscarriage rate was 32.6%. Although the overall probability of live birth was lower and the odds of intrauterine fetal demise (IUFD) of the surviving co-twin were higher in MCMA pregnancies, a clinically important finding was that 82.8% of MCMA pregnancies that did not end in miscarriage before 24 completed weeks ultimately resulted in live birth. This conditional finding suggests that, once an MCMA pregnancy progresses beyond the period of early pregnancy loss after RFA, the probability of achieving live birth may be encouraging.

Nevertheless, the secondary analysis excluding miscarriages provides additional clinically relevant information for counseling patients whose pregnancies continue beyond 24 weeks. In this subgroup, 24 of 29 MCMA pregnancies resulted in live birth, corresponding to a conditional live-birth rate of 82.8%.

The results of the present study can be interpreted in the context of two major reports of RFA in complicated monochorionic pregnancies. Kumar et al. evaluated 100 consecutive pregnancies undergoing selective reduction using RFA and reported an overall live-birth rate of 78%, a co-twin demise rate of 12%, and a median gestational age at delivery of approximately 35.2 weeks [23]. Similarly, the systematic review and meta-analysis by Gaerty et al., which included 320 RFA procedures, reported a pooled live-birth rate of 81.3%, a co-twin death rate of 14.7%, and a mean gestational age at delivery of 34.7 weeks [24]. The conditional live-birth rate of 82.8% and the mean gestational age at delivery of 34.5 weeks observed among MCMA pregnancies in our study were numerically within the range reported in these larger RFA series.

These comparisons should, however, be interpreted cautiously.The cohorts reported by Kumar et al. and Gaerty et al included heterogeneous monochorionic pregnancy configurations and indications, whereas the present analysis specifically evaluated MCMA pregnancies as a distinct group. Thus, the numerical similarity does not establish equivalence, but it indicates that favorable live-birth outcomes can occur in a substantial proportion of MCMA pregnancies that progress beyond the early loss period.

An important strength of the present study is the comparatively large number of MCMA pregnancies. Only five MCMA pregnancies were included in the 100-case series reported by Kumar et al [25], and Gaerty et al. noted that outcomes could not be stratified according to the type of multiple pregnancy in many of the studies included in their meta-analysis [24]. The inclusion of 43 MCMA pregnancies in the current cohort therefore provides additional information regarding a pregnancy configuration that has generally been represented by very small numbers in previous RFA studies.

IUFD of the surviving co-twin at 24 weeks or later occurred in 11.6% of MCMA pregnancies, a proportion numerically close to the co-twin demise rates of 12% reported by Kumar et al. and 14.7% reported in the Gaerty meta-analysis [24, 25]. However, IUFD was significantly more frequent in MCMA than in MCDA pregnancies in our cohort. Notably, four of the five IUFD events in the MCMA group occurred in pregnancies in which a major fetal anomaly was the indication for selective reduction. This clustering

suggests that the higher IUFD rate may have been influenced partly by differences in case mix and underlying fetal pathology rather than by monoamnionicity alone.

A major structural or genetic abnormality in the reduced fetus may sometimes be a marker of broader biological complexity within the pregnancy. The surviving co-twin may share an underlying genetic susceptibility or may have subtle abnormalities that are not detectable during prenatal evaluation. However, these possibilities were not directly investigated in the present study, and no causal relationship between the anomaly in the reduced fetus and subsequent IUFD of the surviving co-twin can be established. Furthermore, the association between MCMA pregnancy and IUFD remained statistically significant after adjustment for RFA indication. The small number of IUFD events and the wide confidence interval indicate that the magnitude of this association remains imprecise.

The anatomical characteristics of MCMA pregnancies may also contribute to the continuing vulnerability of the surviving fetus. The absence of an intertwin membrane and the possibility of umbilical cord entanglement can expose the pregnancy to cord-related complications even after successful interruption of the target fetal circulation. Nevertheless, the independent contribution of cord entanglement to fetal death remains uncertain, and it should not be considered the sole explanation for the higher IUFD rate [26]. The increased risk is likely multifactorial and may reflect the combined effects of monoamniotic anatomy, underlying fetal pathology, procedural factors, and residual differences in disease severity.

PPROM was significantly less frequent in MCMA than in MCDA pregnancies in the analysis of all treated pregnancies, with rates of 14.0% and 39.1%, respectively. After adjustment for maternal age, gestational age at RFA, and RFA indication, MCMA pregnancy remained associated with a lower risk of PPROM (adjusted RR, 0.366; 95% CI, 0.155–0.862; p = 0.021). The PPROM rate observed in the MCMA group was numerically similar to the pooled rate of 17.7% reported after RFA in the Gaerty meta-analysis [25]. A 20-year cohort comparing selective-reduction techniques also reported PPROM before 32 weeks in approximately 14.5% of pregnancies treated using RFA [23]. After excluding pregnancies ending in miscarriage, PPROM occurred in 13.8% of MCMA pregnancies and 35.7% of MCDA pregnancies. Although the direction of the association was similar, the adjusted difference was no longer statistically significant in this conditional analysis (adjusted RR, 0.404; 95% CI, 0.146–1.121; p = 0.082). The higher PPROM rate in the MCDA group may partly reflect the greater prevalence of TTTS, in which polyhydramnios and increased membrane tension may predispose to membrane rupture. Nevertheless, residual confounding related to disease severity, membrane characteristics, and procedural complexity cannot be excluded.

Among pregnancies resulting in live birth, no statistically significant differences were identified between MCMA and MCDA pregnancies in gestational age at delivery, birth weight, Apgar scores, preterm birth, NICU admission, SGA, RDS, or neonatal death. The mean gestational age at delivery in the MCMA group was 34.5 weeks, which was close to the mean of 34.7 weeks reported in the Gaerty meta-analysis and slightly lower than the median of approximately 35.2 weeks reported by Kumar et al. [25, 24]. These

findings suggest that, when live birth was achieved, the measured short-term delivery and neonatal outcomes were broadly comparable between MCMA and MCDA pregnancies.

The principal strengths of this study include the relatively large MCMA cohort, the direct comparison of MCMA and MCDA pregnancies managed at the same tertiary fetal medicine center, the consistent classification of losses before 24 weeks as miscarriage, and the use of adjusted regression models accounting for maternal age, gestational age at RFA, and RFA indication. The study also provides both an all-pregnancy estimate of live birth and a complementary conditional estimate among pregnancies that did not end in early loss, allowing the clinical course following RFA to be described more comprehensively.

Several limitations should be considered. The retrospective design should be taken into account when interpreting the findings. In addition, because the study did not include a comparison group treated using another vascular-occlusion technique, it cannot establish the comparative efficacy of RFA.

Taken together, the observed outcomes support the clinical feasibility of RFA and suggest that acceptable live-birth outcomes can be achieved in selected MCMA pregnancies. In particular, more than four-fifths of MCMA pregnancies that progressed beyond miscarriage before 24 weeks resulted in live birth. This information may be useful for individualized counseling, while emphasizing that the overall prognosis remains influenced by the underlying indication, fetal pathology, and the intrinsic risks of monoamniotic pregnancy. However, these findings should not be interpreted as definitive evidence of the comparative safety of RFA.

Conclusion

Radiofrequency ablation (RFA) achieved acceptable perinatal outcomes in selected complicated monochorionic monoamniotic (MCMA) pregnancies and appears to be a clinically feasible option for selective fetal reduction in this high risk population. Among pregnancies resulting in live birth ,gestational age at delivery, birth weight and short term neonatal outcome were generaly comparable between MCMA and MCDA pregnancies .Although the overall live birth rate was lower and the risk of intrauterine demise of the surviving co-twin was higher in the MCMA group, these differences are likely to reflect the intrincically higher baseline risk associated with MCMA pregnancies rather than the RFA procedure itself. Nevertheless, among MCMA pregnancies that did not end in miscarriage befor 24 weeks ,82.8% resulted in live birth resulted in live birth. Because this study did not include a comparison group managed with an alternative vaso-occlusive technique, the relative efficacy and safety of RFA cannot be definitively established.Fuether comparative studies are warranted ,while curful patient selection, individualized counseling and close antenatal surveillance remain essential.

Declarations

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.MEDICINE.REC.1403.014) and was conducted in accordance with the Declaration of Helsinki. Written informed consent for the RFA procedure was obtained from all patients. The requirement for additional consent for the retrospective use of clinical data was [waived by the ethics committee/fulfilled through written research consent]. Patient confidentiality was protected by assigning a unique identification code to each record.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Contribution

FRS conceived and designed the study. MT collected the data and performed the statistical analyses. MM drafted the manuscript.FRS, MS, BS, FG, and NS contributed to data interpretation, critically revised the manuscript for important intellectual content, and approved the final version.

Acknowledgement

The authors thank Tehran University of Medical Sciences, the staff of Yas Hospital, and all patients whose data contributed to this study.

Data Availability

The datasets generated and analyzed during the current study are not publicly available because they contain information that could compromise participant confidentiality but are available from the corresponding author on reasonable request.

References

1. Gao L, et al. Correlation analysis of adverse outcomes for the selective reduction of twin pregnancies. BMC Pregnancy Childbirth. 2022;22(1):417.
2. Khalil A, et al. ISUOG Practice Guidelines (updated): role of ultrasound in twin pregnancy. Ultrasound Obstet Gynecol. 2025;65(2):253.
3. Sorrenti S, et al. Counselling in fetal medicine: complications of monochorionic diamniotic twin pregnancies. J Clin Med. 2024;13(23):7295.
4. Gynaecologists MD. K.L.B.o.b.o.R.C.o.O.a., *Management of Monochorionic Twin Pregnancy Green-Top Guideline 51 (2024 Partial Update)*. Int J Obstet Gynecol. 2025;132:e98–129.
5. Committee S. .S.a.Q., *Society for Maternal-Fetal Medicine Special Statement: Updated checklists for management of monochorionic twin pregnancy*. Pregnancy, 2026. 2.
6. Chu TY, et al. A novel technique with cool-tip radiofrequency ablation for selective fetal reduction in complicated monochorionic twin. Taiwan J Obstet Gynecol. 2025;64(2):298–302.
7. Sokou R, et al. Neonates at Risk: Understanding the Impact of High-Risk Pregnancies on Neonatal Health. Medicina. 2025;61(6):1077.
8. Wei J, et al. Complications in multiple gestation pregnancy: A cross-sectional study of ten maternal-fetal medicine centers in China. Oncotarget. 2016;7(21):30797–803.
9. Deng C, et al. Perinatal outcomes of spontaneous single fetal death in monochorionic twin pregnancies: a single-center retrospective study. Front Med. 2025;12:1646852.
10. Miller RS, et al. Society for Maternal-Fetal Medicine Consult Series# 72: Twin-twin transfusion syndrome and twin anemia-polycythemia sequence. Am J Obstet Gynecol. 2024;231(4):B16–37.
11. Li D, Wang X. *Ultrasound Assessment of First-Trimester Pregnancy and Complications*, in *Ultrasonography of the Female Reproductive System*. Springer; 2025. pp. 279–312.
12. Huang H-w, Lan K-C. Discordance between chorionicity and embryo transfer number: Four cases report and literature review. Taiwan J Obstet Gynecol. 2026;65(1):55–9.
13. Pitt T, Chmait RH, Monson MA. Monochorionic twin gestation. Clin Obstet Gynecol. 2025;68(3):366–82.
14. Klaritsch P. Complications in monochorionic twin pregnancies. J Perinat Med. 2026;54(1):72–83.
15. Zhang YH et al. New radiofrequency ablation procedure for selective reduction in complicated monochorionic twin or triplet pregnancy using multistep, incremental expansion technique. 2024. 63(4): pp. 522–8.
16. Rahimi-Sharbaf F, et al. Radiofrequency ablation for selective fetal reduction in complicated Monochorionic twins; comparing the outcomes according to the indications. BMC Pregnancy Childbirth. 2021;21(1):189.
17. Prasetyadi FOH, Tedyanto CP, Saraswati V. Selective Fetal Growth Restriction in Monochorionic Twin Pregnancy: A Review of Current Literature on Diagnostic and Therapeutic Updates. Siriraj Med J. 2026;78(2):164–74.

18. Jeong SY, et al. Efficacy and safety of radiofrequency ablation for hyperparathyroidism: a meta-analysis and systematic review. Eur Radiol. 2025;35(10):6583–97.
19. International Society of Ultrasound in Obstetrics and Gynecology (ISUOG). ISUOG Practice Guidelines (updated) :Role of ultrasound in twin pregnancy. Ulterasound in Obstetrics & Gynecology; 2025.
20. Robyr R, Yamamoto M, Ville Y. Selective feticide in complicated monochorionic twin pregnancies using ultrasound – guided bipolar cord coagulation. BJOG. 2005.
21. Sugibayashi R, Ozawa K, Sumie M, Wada S, Ito Y, Sago H. Forty cases of twin reversed arterial perfusion sequence treated with radiofrequency ablation using the multistep coagulation method: a single-center experience. Prenat Diagn. 2016;36(5):437–43.
22. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol. 2004;159(7):702–6.
23. van Hoek MJC, van Klink JMM, Verweij EJT, Middeldorp JM, Haak MC, Lopriore E, et al. Perinatal outcome after selective fetal reduction in monochorionic twin pregnancies: a comparison of techniques over a 20-year period. Prenat Diagn. 2023;43(8):1028–35.
24. Gaerty K, Greer RM, Kumar S. Systematic review and meta-analysis of perinatal outcomes after radiofrequency ablation and bipolar cord occlusion in monochorionic pregnancies. Am J Obstet Gynecol. 2015;213(5):637–43.
25. Kumar S, Paramasivam G, Zhang E, Jones B, Noori M, Prior T, et al. Perinatal- and procedure-related outcomes following radiofrequency ablation in monochorionic pregnancy. Am J Obstet Gynecol. 2014;210(5):454. e1-454.e6.
26. Rossi AC, Prefumo F. Impact of cord entanglement on perinatal outcome of monoamniotic twins: a systematic review of the literature. Ultrasound Obstet Gynecol. 2013;41(2):131–5.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFile1.docx