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A Systematic Review and Meta-Analysis of Clinical Effectiveness of Intravenous Magnesium Sulphate in the Treatment of Acute Fast Atrial Fibrillation in Non-surgical Adult Patients

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Abstract

Atrial fibrillation (AF) is the most common heart rhythm disorder in the elderly, and it contributes significantly to patient morbidity and mortality. A variety of medications, including amiodarone, beta-blockers, and calcium channel blockers, are commonly used to manage AF. Often, intravenous magnesium (IV Mg) is used as an adjunctive therapy for rate and rhythm control; however, its efficacy in managing fast AF has been controversial, with previous meta-analyses yielding conflicting results. This meta-analysis sought to establish the effectiveness of IV Mg in the treatment of fast AF by incorporating data from a recently concluded randomised controlled trial (RCT) on the same subject. Six RCTs, including 480 patients, comparing IV Mg with placebo in the treatment of fast AF were retrieved after an extensive search of electronic databases. The Mantel-Haenszel (MH) random-effects model was used to estimate the mean effect size across all the included studies. The differences among treatment groups for nominal variables were documented as odds ratios (ORs) with 95% confidence intervals (CIs). The pooled analysis showed that IV Mg given as an adjunct to guidelines-recommended medications had a significant positive impact in achieving rate control (OR: 2.15, 95% CI: 0.98, 4.73, $P = 0.03$), with no substantial heterogeneity ($I^2 = 60\%$) as compared to placebo. Similarly, IV Mg was superior to placebo in converting AF rhythm to sinus rhythm (OR: 1.64, 95% CI: 0.90, 2.99, $P = 0.18$), with moderate heterogeneity ($I^2 = 34\%$). On safety profile analysis, flushing was more frequently observed in patients who were treated with IV Mg than in those who were given a placebo (OR: 14.12, 95% CI: 3.16, 63.20, $P < 0.001$), with no statistically significant heterogeneity detected ($I^2 = 0\%$). The overall OR numerically favoured a higher risk of hypotension with IV Mg compared to placebo; however, the result did not reach statistical significance, and the CI was extremely wide. In conclusion, the meta-analysis establishes that IV Mg administered as an adjunct to the standard guidelines-recommended care is significantly effective for rate control and moderately effective for cardioverting fast AF in adult non-post-operative patients.

Categories: Cardiology, Internal Medicine

Keywords: af rate control, af rhythm control, atrial fibrillation, intravenous magnesium, placebo

Introduction And Background

Atrial fibrillation (AF) is an arrhythmia characterised by chaotic, non-sinus activation of the atria, resulting in fibrillation-like contraction that is ineffective at pumping blood [1]. AF is the most common heart rhythm disorder in the elderly, and it contributes significantly to patient morbidity and mortality [2]. Clinical confirmation of AF is done by an electrocardiogram (ECG) tracing, which is characterised by the absence of consistent P waves and an irregular QRS complex [1]. Depending on the state of the atrioventricular node and its reaction to the inhibitory vagus nerve and sympathetic tone stimulation, AF can lead to a rapid heart rate or rapid ventricular response (RVR), also known as fast AF, with a typical heart rate of more than 110 beats per minute [3]. Fast AF reduces ventricular blood filling time and hence cardiac output, increases myocardial cells' oxygen consumption, and can potentially induce tachycardia, cardiomyopathy, and angina [3,4]. If left untreated in an acute setting, fast AF can substantially worsen patient outcomes through rate-related cardiac ischaemia and cardiomyopathy, and may potentially precipitate cardiogenic shock [5,6]. In the acute phase, AF can cause sudden cardiac arrest, and if prolonged and chronic, it is a major risk factor for thromboembolic stroke [2].

The treatment of fast AF is either through electrical cardioversion or chemical (medical) cardioversion, with haemodynamic instability being the major determinant of choice [7]. Haemodynamically unstable patients undergo direct current (DC) cardioversion, while those who are stable receive rate-limited medical treatment [7]. A range of rate-limiting medications and antiarrhythmic agents, including digoxin, beta-blockers, amiodarone, and calcium channel blockers, are recommended by the latest guidelines for use in the treatment of fast AF [7]. Often, in clinical settings, intravenous magnesium (IV Mg) is used as supplementary therapy in treating fast AF; the rationale behind its use is based on the physiological and

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pharmacological properties of the element [8]. Magnesium stabilises myocardial cells by acting directly on myocardial potassium ion channels and also exerts voltage-dependent and indirect influences on sodium and calcium channels, and thus regulates the electrical activity at the atrioventricular node, resulting in a reduction in heart rate and a reduction in the frequency of arrhythmia [4]. Furthermore, magnesium can act as a calcium antagonist, inhibiting ligand-gated calcium channels in myocardial cells. In principle, these properties may also reduce sinus node depolarisation frequency and extend the refractory period of the atrioventricular node, thereby reducing heart rate [9].

However, the scientific evidence supporting the efficacy of IV Mg use in the treatment of fast AF remains weak, with currently randomised controlled trials (RCTs) showing conflicting or inconclusive results [10,11]. In a recently published RCT, the use of IV Mg in a cohort of patients with fast AF found no added benefit in achieving rate or rhythm control compared to the standard guidelines-recommended treatment or placebo [12]. In contrast, the results from two different RCTs concluded that IV Mg is effective for rate control early in the treatment of patients with fast AF [13,14]. Four previous meta-analyses combining data from RCTs on the effectiveness of IV Mg for the treatment of fast AF were performed and yielded conflicting results [15–18]. Recently, an additional RCT on the effectiveness of IV Mg in the management of fast AF was published, so we performed an updated meta-analysis incorporating the new available data to determine the effectiveness of IV Mg as an adjunct in the treatment and control of both rate and rhythm in fast AF. By combining data from individual trials, this meta-analysis aims to determine whether IV Mg provides a clinically meaningful benefit in treating fast AF in adults and to resolve inconsistencies in the existing evidence.

Review

Methodology

This research followed the steps and guidance outlined in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) protocol [19]. To reduce bias, ensure transparency, and avoid duplicating a systematic review already underway, verification by scrutinising the International Prospective Register of Systematic Reviews (PROSPERO) database was done, and our review was also registered in the same database (ID: CRD420261335179). A literature search was conducted in the electronic databases PubMed, Cochrane, ClinicalTrials.gov, and Ovid Medline, with no publication date restrictions, to capture all available RCTs. Medical Subject Headings (MeSH) and keywords like ‘magnesium’, ‘magnesium sulphate’, ‘intravenous magnesium’, ‘atrial fibrillation’, ‘atrial fibrillation with rapid ventricular rate’, and ‘fast atrial fibrillation’ were used to conduct the searches in electronic databases. We also manually screened the reference lists of the included studies to identify additional relevant randomised trials. Although major databases such as EMBASE were unavailable, this supplementary step helped reduce the risk of selection bias. No search restrictions were applied. Database-specific search strategies are presented in the Appendices to support transparency and reproducibility.

Study Selection and Data Extraction

Three reviewers (KM, WC, and DPN), working independently, examined all available texts against the pre-set inclusion and exclusion criteria. Discrepancies at both the title/abstract and full-text screening stages were resolved through discussion and consensus, with a fourth reviewer available to adjudicate if needed. The first step of citation review involved screening by just going through the title and abstract to determine suitability for initial inclusion. Following this step, full-text articles were retrieved and thoroughly reviewed to come up with suitable articles for the final inclusion in the systematic review. Studies included in the systematic review were RCTs comparing IV Mg to placebo, in addition to the guidelines-recommended treatment or care, with the result considered as a positive effect if there was heart rate reduction and/or cardioversion to sinus rhythm. Several studies were discarded because either IV Mg was compared with other fast AF management modalities other than placebo (i.e., compared with electrocardioversion or to antiarrhythmics), the baseline pulse rate was normal or slow and not involving fast AF, patients involved had supraventricular tachycardia or other arrhythmias not AF, patients involved had undergone a surgical procedure, oral magnesium therapy was used to treat AF, IV Mg was used as prophylaxis against occurrence of AF, study findings were not recorded in English, or the study had non-human subjects. Each excluded study needed to have a reason for exclusion clearly documented. Differences in the retrieved data were resolved through discussion among the reviewers to reach a consensus.

The final RCTs meeting the inclusion criteria were further assessed for quality using a five-point Jadad scale (higher scores indicating higher-quality trials), which assigns scores based on parameters like randomisation, blinding, and documentation and handling of all dropouts and the reasons [20]. In addition to the Jadad scoring, we assessed the quality of the included studies using the Cochrane Risk of Bias 2 (RoB 2) tool [21]. This framework evaluates five domains: bias arising from the randomisation process, deviations from the intended intervention, missing outcome data, outcome measurement, and selection of the reported result [21]. Overall judgments were classified as low risk, some concerns, or high risk [21]. Any disagreements in risk-of-bias assessments were resolved through discussion among the three reviewers, with a fourth reviewer consulted when necessary.

Outcome Evaluation

The main efficacy endpoint was successful heart rate reduction and/or rhythm reversion of AF to sinus rhythm as specified for each individual trial, while the secondary outcome included the risk of side effects such as bradycardia, hypotension, and flushing.

Statistical Analysis

The available data were pooled and analysed using Review Manager (RevMan) version 7.12.0 (Cochrane Collaboration, London, UK). The Mantel-Haenszel (MH) random-effects model was used to estimate the mean effect size across all the included studies. The differences among treatment groups for nominal variables were documented as odds ratios (ORs) with 95% confidence intervals (CIs). ORs greater than 1.0 favoured IV Mg, while those less than 1.0 favoured placebo. Statistical heterogeneity was assessed using the I^2 statistic. Values of 0-25% were considered indicative of low heterogeneity, 25-50% of moderate heterogeneity, and greater than 50% of substantial heterogeneity. The choice of statistical model was based on the degree of heterogeneity: fixed-effects models are generally used when heterogeneity is low, whereas random-effects models are preferred when it is substantial. As our analysis indicated substantial heterogeneity, we used a random-effects meta-analysis with the Mantel-Haenszel method. A Mantel-Haenszel continuity correction was applied to account for zero-event data. Sensitivity analyses were prespecified to assess the robustness of the findings, where appropriate, but were not conducted because too few studies were included in the meta-analysis.

Publication bias was assessed visually using funnel plots and formally using Egger's regression test. An intercept with a P-value of less than 0.05 was considered indicative of either small-study effects or potential publication bias.

Findings

In total, 1,035 publications were initially retrieved, including 137 duplicate citations (Figure 1). Eventually, 47 published studies were considered suitable for further review after the initial title and abstract screening. The full texts for the remaining 47 studies were reviewed, and 41 studies were excluded for reasons outlined in Figure 1. There was an initial disagreement among the reviewers on whether to include or exclude one trial; it was resolved to exclude the trial after discussion among the reviewers themselves without the need to involve a fourth reviewer as an arbitrator.

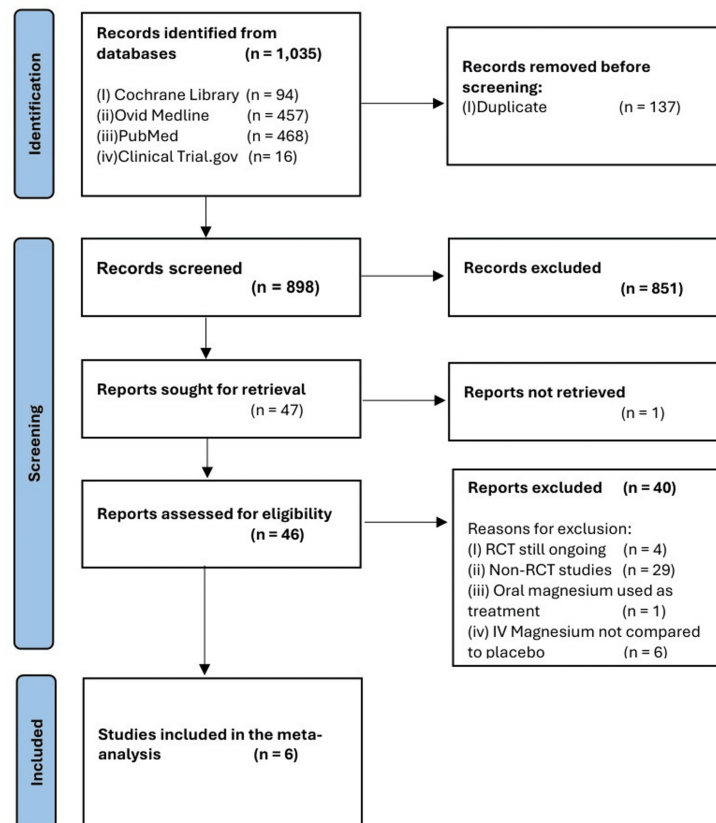


FIGURE 1: Flow chart visualising study extraction.

Finally, six studies were included, with a total of 480 patients, of which 242 received IV Mg, and 238 in the control arm received placebo [12,22-26]. There was complete concurrence among reviewers regarding the final RCTs included for review. The final six studies were published in English, and four of the six were double-blinded, one was triple-blinded [25], and one had unknown blinding status [12,22-26]. The total dose of IV Mg given to patients with fast AF varied from 2.5 to 10 mg. The definition of rate control varied across studies; one study defined heart (pulse) rate control as a 20% reduction from baseline heart rate, while other studies defined rate control as a heart (pulse) rate less than 100 beats per minute [12,22,25,26]. One study did not specify the exact criteria used to define rate control [24]. Four studies examined both rate and rhythm control [22,23,25,26], while two studies examined heart rate alone [12,24]. Time-to-outcome measurements across all studies ranged from two to 24 hours [12,22-26]. Five studies were classified according to the Jadad score as having a high quality, with a score of 3 or more: three studies had a Jadad score of 5, one study had a score of 4, and one study had a score of 3 [12,23-26]. One study included was of poor quality with a Jadad score of 1 [22]. The study characteristics are summarised in Table 1.

Study (year)	Jadad score	Blinding	Treatment vs. placebo	Number of patients involved in the study	Placebo	IV Mg	Inclusion rhythm	Definition of rate control	Outcome measured	Time to outcome in hours
Benhalla et al. (2015) [22]	1	UK	Mg 3 g	30	16	14	AF with HR > 100 bpm	HR < 100 bpm	Rate rhythm	N/A
Brodsky et al. (1993) [23]	3	DB	Mg 10 g	18	8	10	AF with HR 100-200 bpm	HR < 90 bpm for > 60 minutes or at 24 hrs	Rate rhythm	24
Chu et al. (2009) [24]	4	DB	Mg 2.5 g	48	24	24	AF with HR > 100 bpm	Decrease in ventricular rate	Rate	2
Davey et al. (2005) [25]	5	TB	Mg 5 g	199	97	102	AF with HR > 120 bpm	HR <100 bpm at 2.5 hrs or 15 bpm reduction in heart rate	Rate rhythm	2.5
Nogic et al. (2022) [12]	5	DB	Mg 5 g	144	73	71	AF with HR > 120 bpm	HR < 100 bpm at 4 hrs or 20% reduction in heart rate from baseline	Rate	4
Walker et al. (1996) [26]	3	DB	Mg 5 g	41	20	21	AF with HR > 100 bpm	HR < 100 bpm	Rate rhythm	4

TABLE 1: Overview of study characteristics.
UK: unknown; DB: double blind; TB: triple blind; N/A: not available; AF: atrial fibrillation; HR: heart rate; IV: intravenous; Mg: magnesium; bpm: beats per minute.

Using the Cochrane RoB 2 tool, three studies were rated as low risk of bias [12,24,25]. Two studies raised some concerns, mainly because of missing outcome data [23,26]. One study was rated as high risk of bias due to concerns about both missing outcome data and outcome measurement [22]. Missing outcome data was the most common source of concern. Table 2 summarises the risk of bias across the included studies. There was no disagreement among the reviewers during the assessment of bias in the included studies.

Study (year)	Bias arising from the randomisation process	Bias due to deviations from the intended intervention	Bias due to missing outcome data	Bias in the measurement of outcome	Bias in the selection of the reported result	Overall
Benhalla et al. (2015) [22]	Low	Low	Some concerns	Some concerns	Low	High risk
Brodsky et al. (1993) [23]	Low	Low	Some concerns	Low	Low	Some concerns
Chu et al. (2009) [24]	Low	Low	Low	Low	Low	Low risk
Davey et al. (2005) [25]	Low	Low	Low	Low	Low	Low risk
Nogic et al. (2022) [12]	Low	Low	Low	Low	Low	Low risk
Walker et al. (1996) [26]	Low	Low	Some concerns	Low	Low	Some concerns

TABLE 2: Summary of Cochrane Risk of Bias (RoB 2) assessment of the included trials.

The baseline characteristics of patients included in the final review are displayed in Table 3. Serum magnesium levels, which were all within normal ranges, were reported in three studies, while mean serum potassium levels, which were again all within the normal range, were reported in two studies [23-25]. Cardiovascular risk factors like smoking and diabetes were infrequently reported, unlike the number of patients with hypertension, which was recorded in three studies [12,23,24].

Study (year)	Age in years	Male %	Female %	Smoker %	HTN %	CCF %	CHD %	Diabetes %	Stroke %	Pulse mean	SBP mean	Serum Mg (mmol/l)	Serum K (mmol/l)
Benhalla et al. (2015) [22]	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Brodsky et al. (1993) [23]	56 (59)	63 (50)	37 (50)	NR	38 (50)	NA	13 (0)	NA	NA	131 (133)	NR	0.9 (1.1)	4.1 (4.2)
Chu et al. (2009) [24]	58 (47)	71 (79)	29/21	NA	25 (8)	0 (0)	NA	NA	NA	140 (125)	120 (125)	0.8 (0.86)	3.8 (3.9)
Davey et al. (2005) [25]	73 (72)	45 (46)	55 (54)	NA	NA	NR	NA	NA	NA	143 (142)	NA	0.88 (0.85)	NA
Nogic et al. (2022) [12]	71 (71)	58 (55)	42 (45)	34 (24)	59 (54)	15 (10)	10 (11)	14 (18)	3 (4)	137 (135)	NA	NA	NA
Walker et al. (1996) [26]	NA	NA	NA	NA	NA	NA	NA	NA	NA	145 (144)	NA	NA	NA

TABLE 3: Characteristics of patients involved in the study.

CHD: coronary heart disease; CCF: congestive cardiac failure; HPT: hypertension; HTN: hypertension; Mg: magnesium; NA: not available; K: potassium; SBP: systolic blood pressure; (): % that received an intervention.

The medication given to control fast AF as per treatment guidelines recommendation and the timing of administration after giving either placebo or IV Mg (intervention) are illustrated in Table 4. Rate and rhythm-control agents used varied across studies, though one study did not record the medication used in

addition to IV Mg or placebo [22]. Digoxin, beta-blockers, calcium channel blockers, and amiodarone were used in most studies, with digoxin emerging as the main primary agent in controlling fast AF [12,23,25,26]. Three studies enforced an initial lockout period in which antiarrhythmic medications other than placebo or IV Mg administration were not allowed [12,24,25], while the other three studies had no lockout period, with standard antiarrhythmic medications being given at the same time, with IV Mg or placebo [22,23,25].

Study (year)	Lockout period in hours	Digoxin %	Beta-blocker %	Calcium channel blocker %	Amiodarone %
Benhalla et al. (2015) [22]	0	NA	NA	NA	NA
Brodsky et al. (1993) [23]	0	100 (100)	0 (0)	0 (0)	0 (0)
Chu et al. (2009) [24]	2	0 (0)	NA	NA	8 (4)
Davey et al. (2005) [25]	0	84 (75)	9 (11)	2 (4)	NA
Nogic et al. (2022) [12]	2	8 (13)	74 (58)	4 (4)	11 (7)
Walker et al. (1996) [26]	0.5	95 (67)	0 (0)	0 (0)	0 (0)

TABLE 4: Illustration of the standard antiarrhythmic medication used in the study and the lockout time enforced.

NA: not reported; (): % that received an intervention.

Assessment of Efficacy Outcomes

In all six studies reviewed, IV Mg significantly improved ventricular rate control compared to placebo in patients with fast AF (OR: 2.15, 95% CI: 0.98, 4.73, $P = 0.03$), and there was substantial heterogeneity among the results ($I^2 = 60\%$) [12,22-26]. The overall OR favoured IV Mg, indicating consistent findings across all six studies [12,22-26]. Additionally, magnesium showed a statistically significant advantage over placebo for rhythm control, measured by the return to sinus rhythm, across all studies (OR: 1.64, 95% CI: 0.90, 2.99, $P = 0.18$), with moderate heterogeneity ($I^2 = 34\%$) [12,22-26]. These results are summarised in Figure 2.

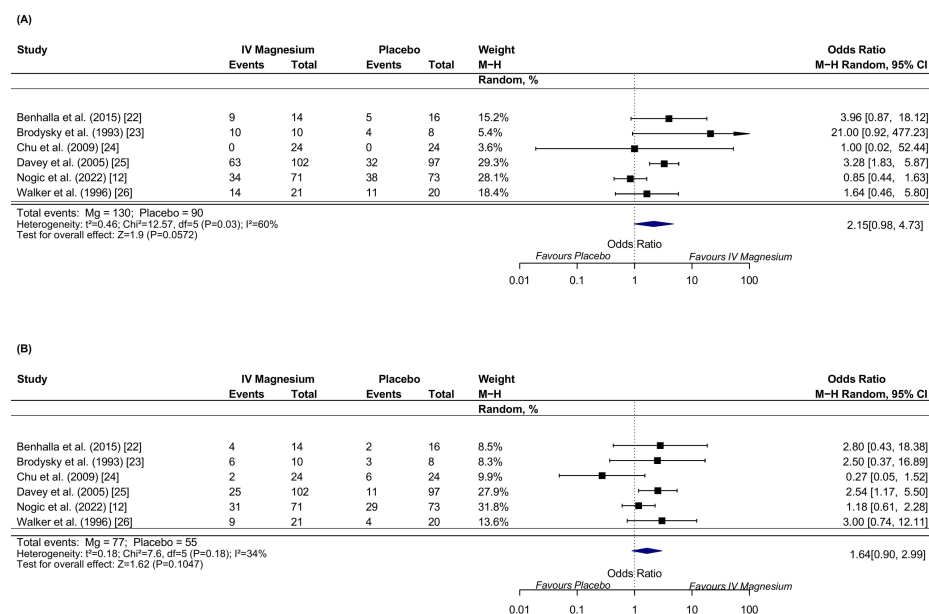


FIGURE 2: Forest plot diagrams comparing the effect of IV magnesium (Mg) vs. placebo for (A) rate control and (B) rhythm control for all six studies.

In studies that used a lockout period in which guidelines recommended antiarrhythmic medications could not be given for a specified period of time, the positive effect of IV Mg on rate control was less pronounced

compared to the overall pooled results (OR: 0.97, 95% CI: 0.55, 1.73, $P = 0.92$), and there was low heterogeneity among these particular studies ($I^2 = 0\%$) [12,24,26]. Likewise, magnesium appeared to be slightly better than placebo for rhythm control, but the evidence was not strong because the CIs were wide due to the small number of studies and events (OR: 1.10, 95% CI: 0.39, 3.15, $P = 0.85$), with significant heterogeneity between studies ($I^2 = 56\%$) [12,24,26]. Figure 3 below is a summary of these findings.

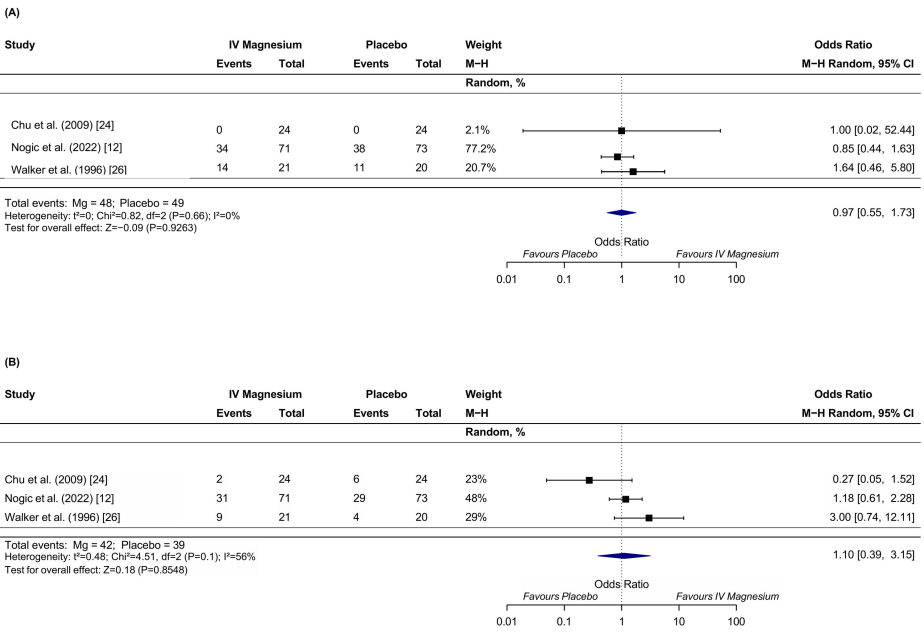


FIGURE 3: Forest plots comparing the effect of IV magnesium (Mg) vs. placebo on (A) rate control and (B) rhythm control among patients with a defined initial lockout period.

In three studies, there was no lockout period, i.e., IV Mg was given at the same time as treatment guidelines-recommended antiarrhythmic medications [22,23,25]. In those studies, IV Mg significantly improved both heart rate (OR: 3.55, 95% CI: 2.08, 6.06, $P < 0.001$) with low heterogeneity ($I^2 = 0\%$) and reversion to rhythm (OR: 2.57, 95% CI: 1.31, 5.01, $P = 0.006$) in patients with fast AF compared to placebo, with no notable heterogeneity ($I^2 = 0\%$) [22,23,25]. These results reinforced IV Mg’s efficacy for rate and rhythm management even when lockout restrictions were not applied. Figure 4 below summarises these findings.

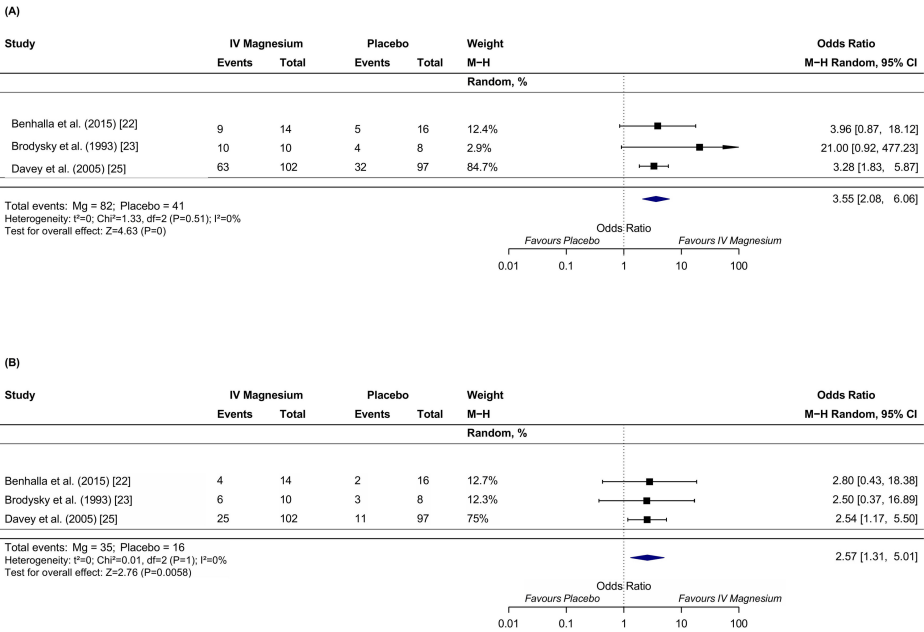


FIGURE 4: Forest plots comparing the effect of IV magnesium (Mg) vs. placebo (A) rate control and (B) rhythm control in patients without an initial lockout period.

IV Mg Safety Overview

Flushing occurred significantly more frequently among patients receiving IV Mg than among those given a placebo (OR: 14.12, 95% CI: 3.16, 63.20, $P < 0.001$) [24-26]. This result was consistent across all three studies, with no statistically significant heterogeneity observed ($I^2 = 0\%$, $P = 0.81$), suggesting a uniform treatment effect [24-26]. The pooled analysis addressing hypotension included only two studies, with zero events recorded in both arms in Chu et al. (2009) [24]. The double zero events are managed through the implementation of the Mantel-Haenszel continuity correction. Although the overall OR indicated a numerically higher risk of hypotension with IV Mg relative to placebo, statistical significance was not achieved, and the CI remained notably broad. The minimal number of events considerably limits the reliability of this estimate. Figure 5 presents forest plots illustrating these findings.

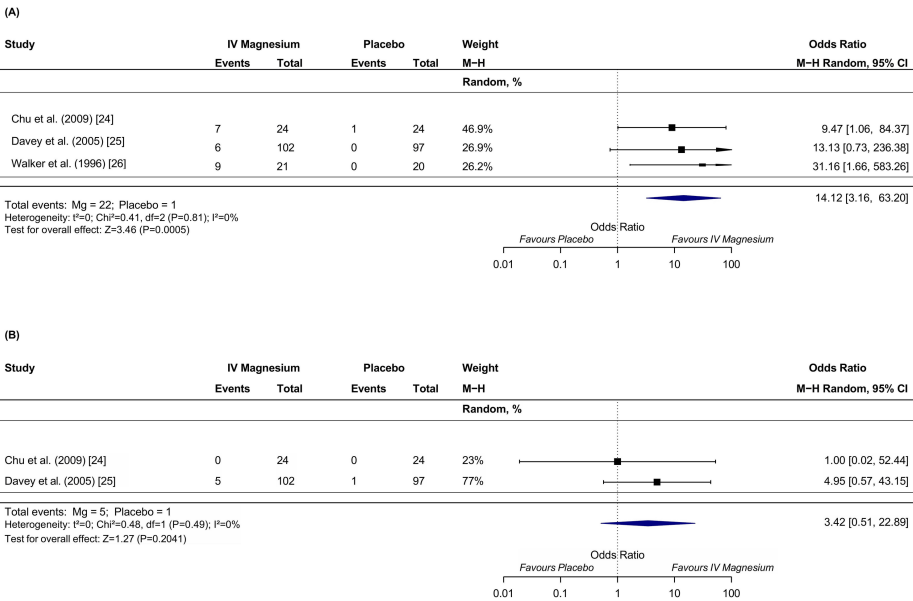


FIGURE 5: Forest plots comparing IV magnesium (Mg) vs. placebo on the likelihood of causing the side effects of (A) flushing and (B) hypotension.

An analysis of publication bias showed the absence of substantial publication bias. The funnel plot for studies using rate control as the endpoint appeared broadly symmetrical [12,22-26]. Egger's test was not statistically significant ($z = 0.47$, $p = 0.660$), indicating no strong evidence of publication bias. However, the substantial heterogeneity ($I^2 = 60\%$) suggests that the slight funnel plot asymmetry may partly reflect true differences between studies rather than bias alone. The funnel plot for studies using rhythm control as the endpoint was symmetrical, with study effects clustered closely around the pooled estimate [12,22-26]. Egger's test also showed no evidence of publication bias ($z = 0.002$, $p = 0.988$), suggesting that the pooled estimate is unlikely to be materially influenced by publication bias or small-study effects. Figure 6 shows the funnel plot diagrams of all included trials for both rate and rhythm endpoints.

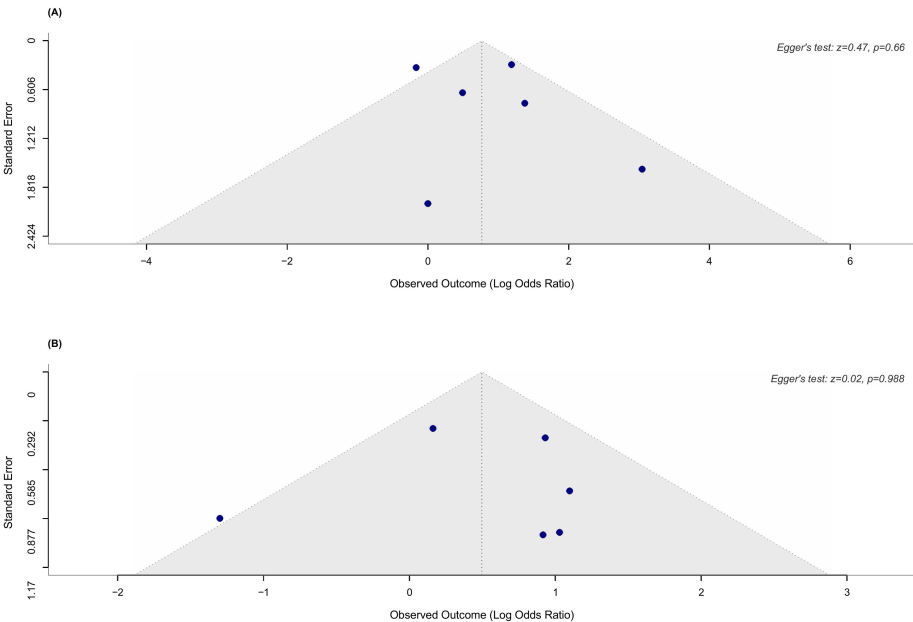


FIGURE 6: Funnel plots using rate control (A) and rhythm (B) as endpoints for six included trials.

Discussion

We conducted a meta-analysis evaluating the effectiveness of IV Mg in the management of acute fast AF in non-surgical adult patients. The meta-analysis reviewed six RCTs [22–26], one of which was recently published in 2022 [12].

Across all six included studies, IV Mg demonstrated a statistically significant improvement in ventricular rate control compared with placebo in patients with rapid AF [22–26]. The pooled OR favoured IV Mg, and heterogeneity across studies was within acceptable limits [22–26]. The inclusion of Chu et al. (2009), which reported zero events in both study arms, was addressed through continuity correction, resulting in minimal impact on the overall estimate [24]. These findings support the efficacy of IV Mg as an adjunct for rate control in AF, aligning with prior meta-analyses conducted on this topic [15,16,18,27]. These findings are theoretically consistent with magnesium's physiological effects on cardiac function. Magnesium stabilises myocardial cells by acting directly on myocardial potassium ion channels and also exerts voltage-dependent effects and indirectly influences sodium and calcium channels, and thus regulates the electrical activity at the atrioventricular node, resulting in slowing of heart rate and reduction of frequency of transmission of an arrhythmia across the heart [27]. Furthermore, magnesium can act as a calcium channel antagonist by inhibiting ligand-gated calcium channels in myocardial cells. In principle, these additional magnesium properties may also reduce sinus node depolarisation frequency and extend the refractory period of cells of the atrioventricular node, thereby reducing heart rate [9].

IV Mg showed a statistically significant advantage over placebo for rhythm control, as evidenced by reversion to sinus rhythm across all studies included in the analysis [22,24–26]. The pooled OR favoured IV Mg, with moderate heterogeneity reported among studies, likely attributable to variations in patient populations, study design, and concurrent medications. Despite this variability, the direction of effect remained consistent, supporting the use of IV Mg as a pharmacological strategy for rhythm conversion to sinus rhythm in AF. This finding aligns with a previous meta-analysis conducted, which demonstrated that IV Mg increases the likelihood of cardioversion from AF to sinus rhythm [18]. However, some preceding RCTs presented conflicting outcomes regarding the restoration of sinus rhythm; two earlier meta-analyses suggested IV Mg had no significant effect on conversion of fast AF to sinus rhythm [15,16].

With respect to the side effect profile, flushing was observed significantly more frequently in patients receiving IV Mg than in those receiving placebo [24–26]. This observation was consistent across all three included studies, with no statistically significant heterogeneity detected ($I^2 = 0\%$, $P = 0.81$), indicating a uniform treatment effect [24–26]. Although the CI was broad due to the relatively limited number of events, the direction and significance of the outcome were clear; therefore, clinicians should recognise that flushing is a predictable and common adverse effect after IV Mg administration. The pooled analysis of hypotension included only two studies [24,25], and both arms of Chu et al. (2009) [24] reported zero events. The overall OR numerically indicated a higher risk of hypotension with IV Mg compared to placebo; however, this finding did not achieve statistical significance, and the CI was exceptionally wide. These results suggest that hypotension occurs infrequently, and the evidence base remains insufficient to support definitive conclusions, as the very limited number of events substantially constrained the reliability of the findings. Consequently, larger studies are needed to adequately characterise hypotension as an adverse effect of IV Mg in the treatment of fast AF. In general, our systematic review and meta-analysis showed that the adverse events associated with magnesium administration were relatively rare and mild, corroborating the findings of previous meta-analyses suggesting that side effects of IV Mg were insignificant and inconsequential [15,16,18,27]. In those few patients who develop side effects to IV Mg, both flushing and hypotension are hypothesised to occur through several mechanisms, including vasodilation, reduced calcium efflux from the sarcoplasmic reticulum, accelerated synthesis of prostacyclin, and inhibition of angiotensin-converting enzyme activity, with an overall effect of diverting blood from systemic circulation into veins and the skin, resulting in hypotension and flushing [28,29].

This study has several notable limitations. Firstly, the meta-analysis includes a relatively small number of studies of varying quality; specifically, four of six RCTs have limited sample sizes, ranging from 18 to 48 participants [22–24,26]. Some studies date back over 25 years and do not report baseline patient information in accordance with current standardised conventions [12,23,25]. Furthermore, details such as baseline potassium levels and the number of patients with heart failure or pre-existing AF were not documented [12,22,25,26]. Allocation concealment was unclear in several studies, with reported Jadad scores ranging from 1 to 5. One study lacked information on allocation concealment and blinding and received a Jadad score of 1 [22]. Additionally, the standard-of-care medications included in our analysis may not accurately reflect the contemporary clinical practice. A significant proportion of patients received digoxin, which is no longer recommended as a first-line agent for rate control monotherapy unless there is concomitant heart failure [30]. Digoxin is now typically reserved for individuals unresponsive to beta-blockers or calcium channel blockers; it remains considered first-line for special cases of heart rate control in patients with fast AF and hypotension or left ventricular dysfunction due to its beneficial positive inotropic effects [30]. The predominance of older studies in this analysis likely explains the higher use of digoxin observed in the studies reviewed. Sensitivity analyses were not conducted because too few trials were included in the meta-analysis, resulting in this meta-analysis being highly vulnerable to distorted effect sizes, misplaced confidence, and unaddressed biases.

The results of this meta-analysis will help clarify the effectiveness of IV Mg in non-surgical adult patients with fast AF. AF is a growing public health issue, and its occurrence is expected to keep rising [31]. Offering more treatment options could ease the overall impact, and magnesium, which is affordable and readily accessible, might offer benefits. Nevertheless, larger RCTs conducted under current research standards are needed before reaching a consensus on the use of IV Mg in the treatment of patients with fast AF.

Conclusions

The meta-analysis examined the clinical effectiveness of IV Mg sulphate for treating acute fast AF in non-surgical adult patients. When administered alongside standard care, IV Mg was significant in controlling heart rate and showed modest effectiveness in restoring sinus rhythm in patients with fast AF. These findings add further support to the evidence of IV Mg use in the setting of acute AF. Although the side effects of IV Mg were generally not clinically significant, flushing occurred more frequently than hypotension, and clinicians should remain aware of these potential adverse effects. The main limitation of the meta-analysis was the relatively small number of total participants in studies, with some of the studies categorised as low quality as assessed using the Jadad score. In future, larger RCTs are needed to provide more conclusive and reliable evidence for the use of IV Mg in managing adult patients with fast AF.

Appendices

Source	Search strategy	Filters/limits	Date of search
Cochrane Library	(magnesium OR magnesium sulphate or MgSO4) AND (atrial fibrillation or af) and randomised	No restrictions	26 February 2026
Ovid Medline	(magnesium OR magnesium sulphate or MgSO4) AND (atrial fibrillation or af) and randomised	No restrictions	26 February 2026
PubMed	(magnesium OR magnesium sulphate or MgSO4) AND (atrial fibrillation or af) and randomised	No restrictions	26 February 2026
ClinicalTrials.gov	(magnesium OR magnesium sulphate or MgSO4) AND (atrial fibrillation or af) and randomised	No restrictions	26 February 2026
Manual search	Reference lists of included studies	No restrictions	26 February 2026

TABLE 5: Summary of search strategies utilised.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Kelvin Mupunga

Acquisition, analysis, or interpretation of data: Kelvin Mupunga, Willmore Chandavengerwa, Durai Pardon Nyabadza, Adelaide Belinda Masungu

Drafting of the manuscript: Kelvin Mupunga

Critical review of the manuscript for important intellectual content: Kelvin Mupunga, Willmore Chandavengerwa, Durai Pardon Nyabadza, Adelaide Belinda Masungu

Supervision: Kelvin Mupunga

Disclosures

Conflicts of interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial relationships:** All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

References

1. Van Gelder IC, Rienstra M, Bunting KV, et al.: 2024 ESC guidelines for the management of atrial fibrillation developed in collaboration with the European Association for Cardio-Thoracic Surgery (EACTS): developed by the task force for the management of atrial fibrillation of the European Society of Cardiology (ESC), with the special contribution of the European Heart Rhythm Association (EHRA) of the ESC. Endorsed by the European Stroke Organisation (ESO). *Eur Heart J*. 2024, 45:3314-414. [10.1093/eurheartj/ehae176](https://doi.org/10.1093/eurheartj/ehae176)
2. Kirchhof P, Curtis AB, Skanes AC, Gillis AM, Samuel Wann L, John Camm A: Atrial fibrillation guidelines across the Atlantic: a comparison of the current recommendations of the European Society of Cardiology/European Heart Rhythm Association/European Association of Cardiothoracic Surgeons, the American College of Cardiology Foundation/American Heart Association/Heart Rhythm Society, and the Canadian Cardiovascular Society. *Eur Heart J*. 2013, 34:1471-4. [10.1093/eurheartj/ehs446](https://doi.org/10.1093/eurheartj/ehs446)
3. Moskowitz A, Chen KP, Cooper AZ, Chahin A, Ghassemi MM, Celi LA: Management of atrial fibrillation with rapid ventricular response in the intensive care unit: a secondary analysis of electronic health record data. *Shock*. 2017, 48:436-40. [10.1097/SHK.0000000000000869](https://doi.org/10.1097/SHK.0000000000000869)
4. January CT, Wann LS, Calkins H, et al.: 2019 AHA/ACC/HRS focused update of the 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association task force on clinical practice guidelines and the Heart Rhythm Society. *J Am Coll Cardiol*. 2019, 74:104-32. [10.1016/j.jacc.2019.01.011](https://doi.org/10.1016/j.jacc.2019.01.011)
5. Lemery R, Brugada P, Cheriex E, Wellens HJ: Reversibility of tachycardia-induced left ventricular dysfunction after closed-chest catheter ablation of the atrioventricular junction for intractable atrial fibrillation. *Am J Cardiol*. 1987, 60:1406-8. [10.1016/0002-9149\(87\)90633-3](https://doi.org/10.1016/0002-9149(87)90633-3)
6. Geng M, Lin A, Nguyen TP: Revisiting antiarrhythmic drug therapy for atrial fibrillation: reviewing lessons learned and redefining therapeutic paradigms. *Front Pharmacol*. 2020, 11:581837. [10.3389/fphar.2020.581837](https://doi.org/10.3389/fphar.2020.581837)
7. Wyse DG, Waldo AL, DiMarco JP, et al.: A comparison of rate control and rhythm control in patients with atrial fibrillation. *N Engl J Med*. 2002, 347:1825-33. [10.1056/NEJMoa021328](https://doi.org/10.1056/NEJMoa021328)
8. Baker WL: Treating arrhythmias with adjunctive magnesium: identifying future research directions. *Eur Heart J Cardiovasc Pharmacother*. 2017, 3:108-17. [10.1093/ehjcvp/pvw028](https://doi.org/10.1093/ehjcvp/pvw028)
9. Bouida W, Beltaief K, Msolli MA, et al.: Low-dose magnesium sulfate versus high dose in the early management of rapid atrial fibrillation: randomized controlled double-blind study (LOMAGHI study). *Acad Emerg Med*. 2019, 26:183-91. [10.1111/acem.13522](https://doi.org/10.1111/acem.13522)
10. Kotecha D: Magnesium for atrial fibrillation, myth or magic? . *Circ Arrhythm Electrophysiol*. 2016, 9:e004521. [10.1161/CIRCEP.116.004521](https://doi.org/10.1161/CIRCEP.116.004521)
11. Ho KM, Sheridan DJ, Paterson T: Use of intravenous magnesium to treat acute onset atrial fibrillation: a meta-analysis. *BMJ Heart*. 2007, 93:1433-40. [10.1136/hrt.2006.111492](https://doi.org/10.1136/hrt.2006.111492)
12. Nogie J, MacPherson M, Aldridge E, et al.: Magnesium in the management of atrial fibrillation with rapid ventricular response. *JACC Clin Electrophysiol*. 2022, 8:800-2. [10.1016/j.jacep.2022.01.017](https://doi.org/10.1016/j.jacep.2022.01.017)
13. Zaouche K, Mhadhbi H, Boubaker R, Baccouche R, Khattech I, Majed K: Magnesium sulfate: an adjunctive therapy in the first hour of management of rapid atrial fibrillation in the emergency department. *Tunis Med*. 2021, 99:225-31.
14. Heitz C, Morgenstern J, Bond C, Milne WK: Hot off the press: low-dose magnesium sulfate versus high dose in the early management of rapid atrial fibrillation: randomized controlled double-blind study. *Acad Emerg Med*. 2019, 26:1093-5. [10.1111/acem.13720](https://doi.org/10.1111/acem.13720)
15. Onalan O, Crystal E, Daoulah A, Lau C, Crystal A, Lashevsky I: Meta-analysis of magnesium therapy for the acute management of rapid atrial fibrillation. *Am J Cardiol*. 2007, 99:1726-32. [10.1016/j.amjcard.2007.01.057](https://doi.org/10.1016/j.amjcard.2007.01.057)
16. Henyan NN, Gillespie EL, White CM, Kluger J, Coleman CI: Impact of intravenous magnesium on post-cardiothoracic surgery atrial fibrillation and length of hospital stay: a meta-analysis. *Ann Thorac Surg*. 2005, 80:2402-6. [10.1016/j.athoracsur.2005.03.036](https://doi.org/10.1016/j.athoracsur.2005.03.036)
17. Gilardi E, Pomero F, Ravera E, et al.: Intravenous magnesium sulfate reduces the need for antiarrhythmics during acute-onset atrial fibrillation in emergency and critical care. *J Clin Med*. 2022, 11:5527. [10.3390/jcm11195527](https://doi.org/10.3390/jcm11195527)
18. Ramesh T, Lee PYK, Mitta M, Allencherril J: Intravenous magnesium in the management of rapid atrial fibrillation: a systematic review and meta-analysis. *J Cardiol*. 2021, 78:375-81. [10.1016/j.jjcc.2021.06.001](https://doi.org/10.1016/j.jjcc.2021.06.001)
19. Page MJ, McKenzie JE, Bossuyt PM, et al.: The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021, 372:n71. [10.1136/bmj.n71](https://doi.org/10.1136/bmj.n71)
20. Clark HD, Wells GA, Huët C, McAlister FA, Salmi LR, Fergusson D, Laupacis A: Assessing the quality of randomized trials: reliability of the Jadad scale. *Control Clin Trials*. 1999, 20:448-52. [10.1016/s0197-2456\(99\)00026-4](https://doi.org/10.1016/s0197-2456(99)00026-4)
21. Sterne JAC, Savović J, Page MJ, et al.: RoB 2: a revised tool for assessing risk of bias in randomised trials. *BMJ*. 2019, 366:l4898. [10.1136/bmj.l4898](https://doi.org/10.1136/bmj.l4898)
22. Benhalla H, Fennich N: P1820. What about magnesium sulfate in atrial fibrillation with acute heart failure? . *European Journal of Heart Failure Volume 17: Abstracts of the Heart Failure 2015 and the 2nd World Congress on Acute Heart Failure*, Seville, Spain, 23-26th May 2015. Wiley, New York, NY; 2015.
23. Brodsky MA, Orlov MV, Capparelli EV, Allen BJ, Iseri LT, Ginkel M, Orlov YS: Magnesium therapy in new-onset atrial fibrillation. *Am J Cardiol*. 1994, 73:1227-9. [10.1016/0002-9149\(94\)90190-2](https://doi.org/10.1016/0002-9149(94)90190-2)
24. Chu K, Evans R, Emerson G, Greenslade J, Brown A: Magnesium sulfate versus placebo for paroxysmal atrial fibrillation: a randomized clinical trial. *Acad Emerg Med*. 2009, 16:295-300. [10.1111/j.1553-2712.2009.00360.x](https://doi.org/10.1111/j.1553-2712.2009.00360.x)
25. Davey MJ, Teubner D: A randomized controlled trial of magnesium sulfate, in addition to usual care, for rate control in atrial fibrillation. *Ann Emerg Med*. 2005, 45:347-53. [10.1016/j.annemergmed.2004.09.013](https://doi.org/10.1016/j.annemergmed.2004.09.013)
26. Walker S, Taylor J, Harrod R: The acute effects of magnesium in atrial fibrillation and flutter with a rapid ventricular rate. *Emerg Med*. 1996, 8:207-13. [10.1111/j.1442-2026.1996.tb00274.x](https://doi.org/10.1111/j.1442-2026.1996.tb00274.x)

27. Enayati A, Gin JH, Sajeev JK, et al.: Efficacy of intravenous magnesium for the management of non-post operative atrial fibrillation with rapid ventricular response: a systematic review and meta-analysis. *J Cardiovasc Electrophysiol*. 2023, 34:1286-95. [10.1111/jce.15911](https://doi.org/10.1111/jce.15911)
28. Bhatti H, Mohmand B, Ojha N, P Carvounis C, L Carhart R: The role of magnesium in the management of atrial fibrillation with rapid ventricular rate. *J Atr Fibrillation*. 2020, 13:2389. [10.4022/jafib.2389](https://doi.org/10.4022/jafib.2389)
29. Elsharnouby NM, Elsharnouby MM: Magnesium sulphate as a technique of hypotensive anaesthesia . *Br J Anaesth*. 2006, 96:727-31. [10.1093/bja/ael085](https://doi.org/10.1093/bja/ael085)
30. January CT, Wann LS, Alpert JS, et al.: 2014 AHA/ACC/HRS guideline for the management of patients with atrial fibrillation: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines and the Heart Rhythm Society. *J Am Coll Cardiol*. 2014, 64:e1-76. [10.1016/j.jacc.2014.03.022](https://doi.org/10.1016/j.jacc.2014.03.022)
31. Bajpai A, Camm AJ, Savelieva I: Epidemiology and economic burden of atrial fibrillation . *US Cardiol Rev*. 2007, 4:14-7. [10.15420/usc.2007.4.1.14](https://doi.org/10.15420/usc.2007.4.1.14)