Reviews in Cardiovascular Medicine

Rev. Cardiovasc. Med. **2024**; 25(5): 152
https://doi.org/10.31083/j.rcm2505152

Systematic Review

Early Mobilization after Cardiac Catheterization via Femoral Artery: A Systematic Review and Meta-Analysis

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Academic Editors: Hiroki Ikenaga, Hiroki Teragawa and Vincenzo Lionetti

Submitted: 4 September 2023 Revised: 20 December 2023 Accepted: 2 January 2024 Published: 30 April 2024

Abstract

Background: Early mobilization is one of the essential components of enhanced recovery after surgery (ERAS) pathways and has been shown to reduce complications and optimize patient outcomes. However, the effect of early mobilization for patients who undergo trans-femoral cardiac catheterization and the time for optimal mobilization timing remains controversial. We aimed to identify the safety of early mobilization and provide the optimum timing for early mobilization for patients undergoing trans-femoral cardiac catheterization. **Methods**: We searched MEDLINE, EMBASE, PubMed, Web of Science, Cochrane databases of systematic reviews, CINAHL, SCOPUS, China National Knowledge Infrastructure (CNKI), Wan Fang Database, and Chinese Science and Technology Periodical Database (VIP) comprehensively for randomized controlled trials associated with early mobilization, to explore its effects on patients after a trans-femoral cardiac catheterization. The risk of bias and heterogeneity of studies was assessed using the Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) and I^2 index, respectively. The comprehensive Meta-analysis (CMA) was adopted to perform the meta-analysis. **Results**: We identified 14 trials with 2653 participants. Early mobilization was associated with significant decrease in back pain (mean difference (MD) = 0.634, 95% CI: 0.23–1.038; p = 0.002), especially in patients receiving instruction for early mobilization in 3 h~4 h versus 5 h~6 h (MD = 0.737, 95% CI: 0.431–1.043; p = 0.000) and 12 h versus 24 h (OR = 5.504, 95% CI: 1.646–18.407; p = 0.006) categories. The results of subgroup analysis also showed a significant risk reduction in urinary retention by early mobilization in 12 h versus 24 h (OR = 5.707, 95% CI: 1.859–17.521; p = 0.002) category. **Conclusions**: Early mobilization has not been shown to increase the risk of bleeding, hematoma, pseudoaneurysm, urinary retention, and pain at the puncture site after trans-femoral cardiac catheterization. Early mobilization is a practical initiative in ERAS, and it may be safe and feasible to advance the mobilization to 2 h~4 h.

Keywords: early mobilization; trans-femoral cardiac catheterization; ERAS; systematic review

1. Introduction

Cardiac catheterization, a minimally invasive procedure accompanied by cardiac catheters placed into vessels, has progressed to encompass a wide range of heart diagnostic and therapeutic procedures, including hemodynamic assessment, coronary and peripheral arterial angiography and intervention, and structural heart disease intervention [1,2]. Currently, diagnostic and therapeutic heart catheterizations are common for electively or emergent procedures for patients with cardiovascular symptoms [3–5].

Femoral access remains a preferred vascular access site for cardiac catheterization with less radiation and contrast than trans-radial access, especially for complex coronary interventions. It is also the predominant approach for transcatheter aortic valve replacement [6–8]. In these procedures, manual or mechanical application of a firm pressure above the puncture site and restricted bed rest in a supine position with the affected leg immobilization after sheath removal are essential [9,10]. Bed rest after trans-femoral cardiac catheterization is necessary to promote the healing of the puncture site and prevent minor to severe complications, including arterial bleeding, hematoma, pseudoaneurysms, and other vascular complications [11,12]. Nevertheless, long-term bed rest is associated with numerous cardiovascular, pulmonary, and muscular complications [13–17]. Many patients who lie in bed without changing position for a long time complain of back pain or urinary discomfort, which can result in increased medical costs due to prolonged hospital stay [18,19].

Shortening the length of bed rest after trans-femoral catheterization may result in improved outcomes following cardiac catheterization procedures. Early mobilization, one of the countermeasures to decrease bed rest complications, has been proven to be a feasible and safe intervention to reduce hospital stay, venous thrombosis and embolisms, and falls [20–22]. However, there is controversy regarding the evidence of optimal time for mobilization following trans-femoral cardiac catheterization. The duration of bed rest after sheath removal ranges from 1 h to 24 h according to the different catheter sizes, the dose of heparin used, and the techniques and protocols in various cardiac centers [23–25]. Chair *et al.* [26] indicated that the length of bed rest for trans-femoral cardiac catheterization could decrease from 12–24 h to 4 h. Gall *et al.* [27] demonstrated that a bed rest duration of 1.5 h in restricted posting was not associated with increased complications. Several studies using arterial closure devices for femoral artery puncture sites also confirmed the feasibility of 6–8 h to ambulation [28,29]. A recent network meta-analysis showed that ambulation could be safely implemented as early as 2 hours after trans-femoral catheterization [30]. Unfortunately, no existing studies involved Chinese patients, and its applicability to Chinese patients remains unclear. This systematic review aimed to summarize recommendations regarding the optimum timing for early mobilization and to identify the safety of early mobilization for patients who underwent trans-femoral cardiac catheterization.

2. Methods

2.1 Study Selection and Search Strategy

We searched the MEDLINE, EMBASE, PubMed, Web of Science, Cochrane databases of systematic reviews, CINAHL, SCOPUS, China National Knowledge Infrastructure (CNKI), Wan Fang Database, and Chinese Science and Technology Periodical Database (VIP) for all relevant studies from the earliest data available to December 2022. The search and reporting procedure followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 checklist [31]. In addition, we manually retrieved and evaluated the reference lists of all the identified studies. All contents and methods were approved by the ethics committee of West China Hospital, Sichuan University (2021, Review No. 591).

Two independent researchers (JYW and JC) performed all searches. Our search strategy was based on the medical subject headings (Mesh) and free-text words, and the main Mesh were as follows: 'Cardiac Catheters', 'Femoral Artery', 'early mobilization', 'Walking' and 'Bed Rest'. Two reviewers (JYW and SYT) independently screened and identified the studies for potential eligibility. We consulted the corresponding author to get a consensus about any controversy. The complete search strategy is shown in **Supplementary Material**.

2.2 Study Inclusion and Exclusion Criteria

The PICOS framework (P for the population of interest, I for intervention, C for comparison group, O for outcome, and S for study design) guided the study process [32,33].

Studies that met the following inclusion criteria were included in this meta-analysis: (1) heart catheterization via femoral artery approach, (2) human studies comparing the safety of different lengths of bed rest with or without altering the patient's position or the angle of beds, (3) participants older than 18 years of age, (4) randomized or quasi-randomized controlled trials involving more than ten patients in each group, (5) the studies provided no less than one clinical outcome, including bleeding, hematoma, pseudoaneurysm at the puncture site, back pain, urinary retention, or bladder catheterization, (6) language: English and Chinese. There were no restrictions concerning patient characteristics or healthcare settings.

We excluded studies if (1) any vascular closure device (VCD) or coagulants was applied to achieve the puncture site hemostasis except a bandage, sandbag, or manual compression, (2) the full text was not available, (3) only the position of the patients or the angle of the beds was altered, but the patients did not get out of bed, (4) the effects to combine early mobilization with other intervention variables (e.g., encouraging exercise and applying ice packs), (5) there was no specific ambulation timing or measurable outcome.

2.3 Type of Intervention and Outcomes

Shortening the post-cardiac catheterization duration of bed rest was the early mobilization group, and the longer duration of bed rest was regarded as the late ambulation group. According to the characteristics of the included studies, we classified different bed rest duration into the following four comparison subgroups: Group A: Comparing 2 h versus 4 h~6 h of bed rest; Group B: Comparing 3 h~4 h versus 5 h~6 h of bed rest; Group C: Comparing 4 h~6 h versus greater than or equal to 8 h of bed rest; Group D: Comparing 12 h versus 24 h of bed rest. The primary outcomes of interest were the incidence of bleeding and hematoma at the puncture site. The secondary outcomes were the incidence of back pain, pseudoaneurysm, urinary retention, and pain at the puncture site.

2.4 Data Extraction

Using Excel, two authors (JYW and SYT) independently extracted and coded data from the qualified studies into standard tables. The original authors would be contacted for further information if data from the included stud-

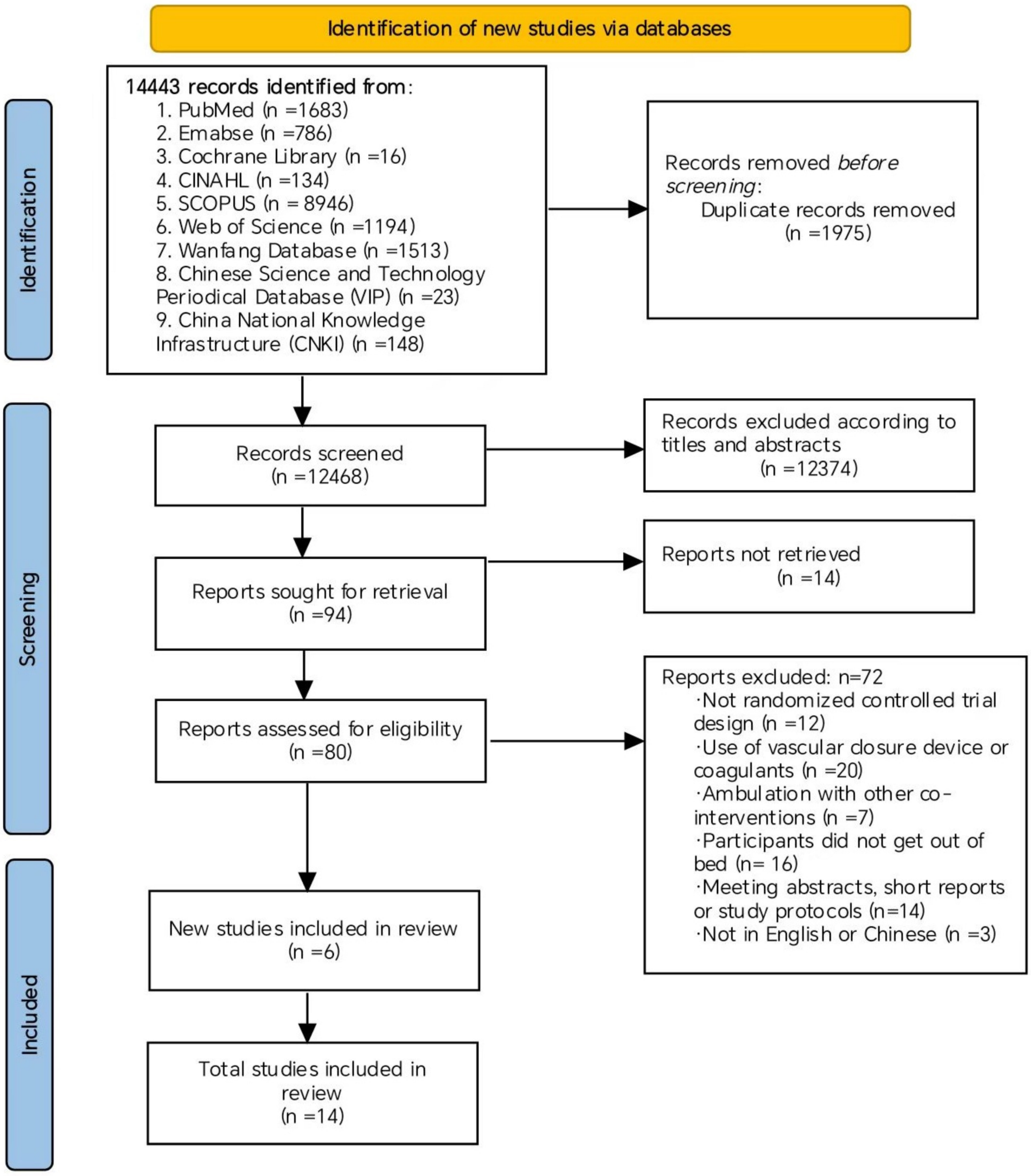

Fig. 1. Flow diagram of the systematic searching process.

ies were insufficient. Any disagreement was verified by the corresponding author. The items included: authors, year of publication, country, setting and location of the study, number of patients, the mean age of patients, study design, duration of the bed rest, hemostasis method, outcomes, and other relevant information.

2.5 Quality and Risk of Bias Assessment

The risk of bias in the included studies was independently evaluated by two authors (JYW and SYT) using the RoB 2 tool [34]. This tool assesses the following key areas of potential bias: randomization methods; deviations from intended intervention; missing outcome data; measurement of outcome; and selection of reported results. The judgment for the domain of RoB 2 is generated by an algorithm and can be ranked as low, high, or show some concerns. Each study is also given an overall judgment of RoB 2 based on the same options [34]. The corresponding author was available for arbitration in any disagreement regarding the ranking process and results.

2.6 Data Synthesis and Statistical Analysis

This study was statistically analyzed using the Comprehensive Meta-Analysis software, Version 2 (Biostat, Englewood, NJ, USA). We pooled the odd ratio (OR), mean difference (MD), and 95% confidence intervals (CI) from separate studies to assess the intended effect sizes. Cochran's Q test and the degree of inconsistency (I^2 index) were used to evaluate the heterogeneity across studies. There was no heterogeneity if the I^2 statistic was less

Fig. 2. Risk of bias (RoB 2) assessment plot for the included randomized controlled trial studies.

than 25%, a low heterogeneity if the I^2 statistic was 25–50%, and a moderate heterogeneity if the I^2 statistic was 50–75%, while the $I^2 > 75\%$ reflected a high heterogeneity [35]. Funnel plots, Egger's test [36], and Begg's test [37] were used to analyze publication bias. Random-effect models that reflected the differences between each study were applied because of the heterogeneity across studies [38]. Subgroup analyses were performed based on the different bed rest duration. A p-value < 0.05 was considered statistically significant.

3. Result

3.1 Selection of Studies

The initial literature search yielded 14,443 studies, of which 1975 studies were excluded after removing duplicates. There were 94 studies eligible for further evaluation after 12,374 studies were excluded because of irrelevant titles and abstracts. At the full-text screening stage, only 80 studies were reviewed because 14 studies did not have the full text, and six studies met the inclusion and exclusion criteria. Then, we added eight eligible studies from the reference review process. Finally, 14 studies with 2653 participants were selected for this meta-analysis. A summary of the PRISMA flow diagram of the study selection process is shown in Fig. 1.

3.2 Selected Studies and Characteristics

The 14 randomized controlled trials involving 2653 participants included 2 Chinese and 12 English studies. Two [39,40] of the fourteen included studies were assigned

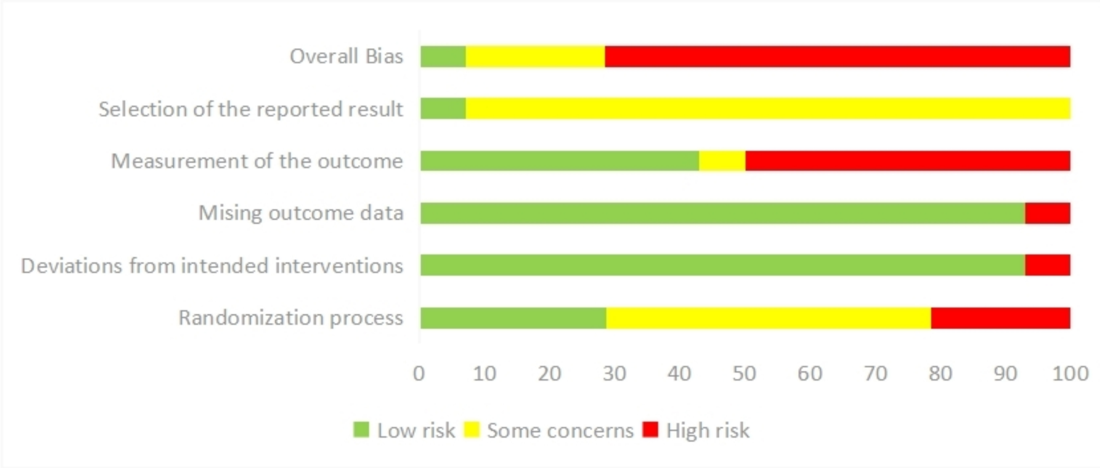

Fig. 3. Weighted summary plot of all the types of bias from the included studies.

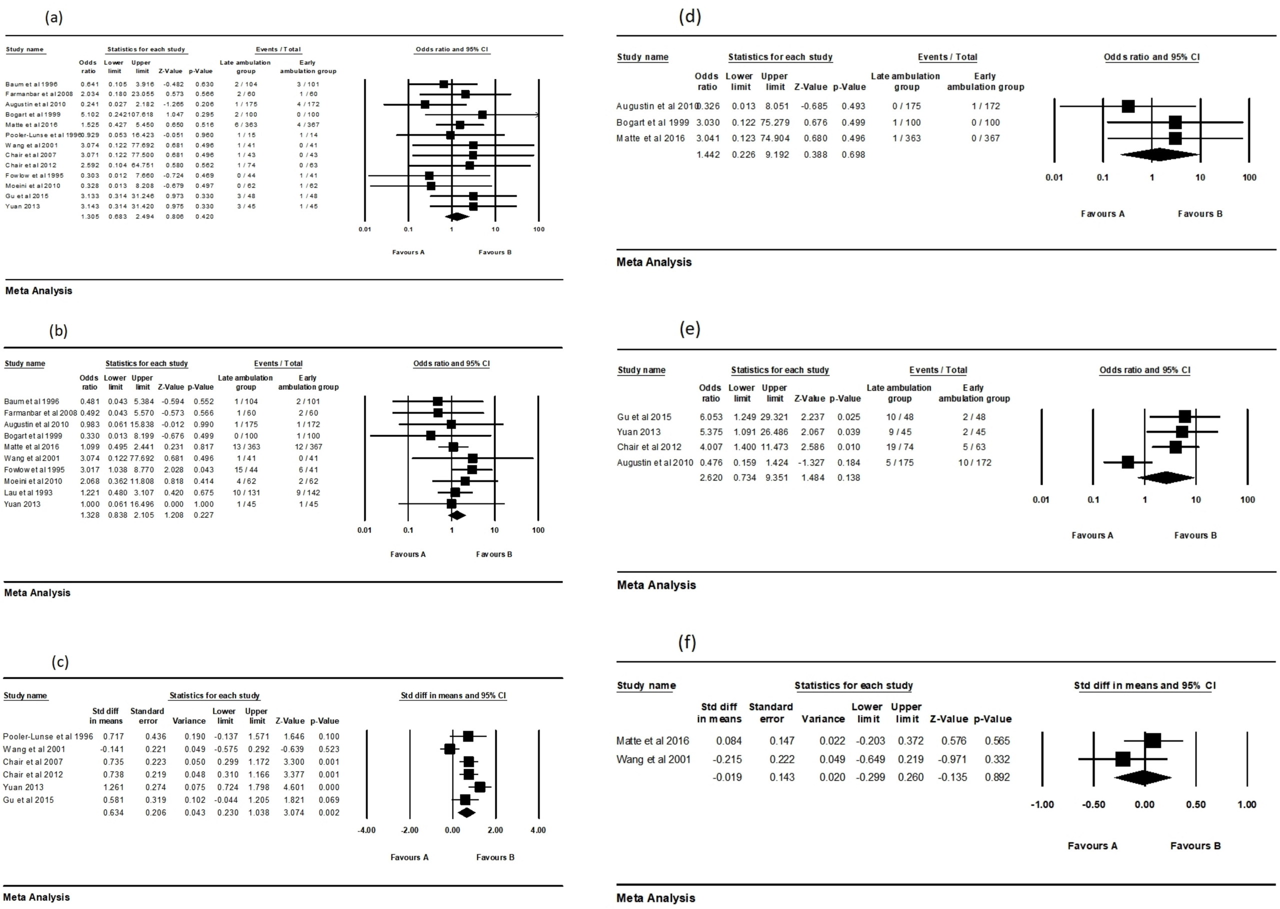

Fig. 4. The results of the overall odds ratio or mean difference for early mobilization effect among different outcomes. (a) Bleeding. (b) Hematoma. (c) Back pain. (d) Pseudoaneurysm. (e) Urinary retention. (f) Pain at the puncture site. The horizontal lines denote the 95% CI, the Square (■) shows the point estimate (the size of the square corresponds to its weight); the diamond shows (◆) the combined overall effects of ambulation at 95% CI. CI, confidence interval.

to Group A with 325 participants, five studies [23,41–44] belonged to Group B with 1388 participants, five [26,29,45–47] were allocated to Group C with 705 participants, and the remaining two Chinese studies [48,49] were in Group D with 235 participants. The mean age of the participants was between 53–67 years. These researches took place across three continents, five studies in North America, seven in Asia, and two in South America, of which four

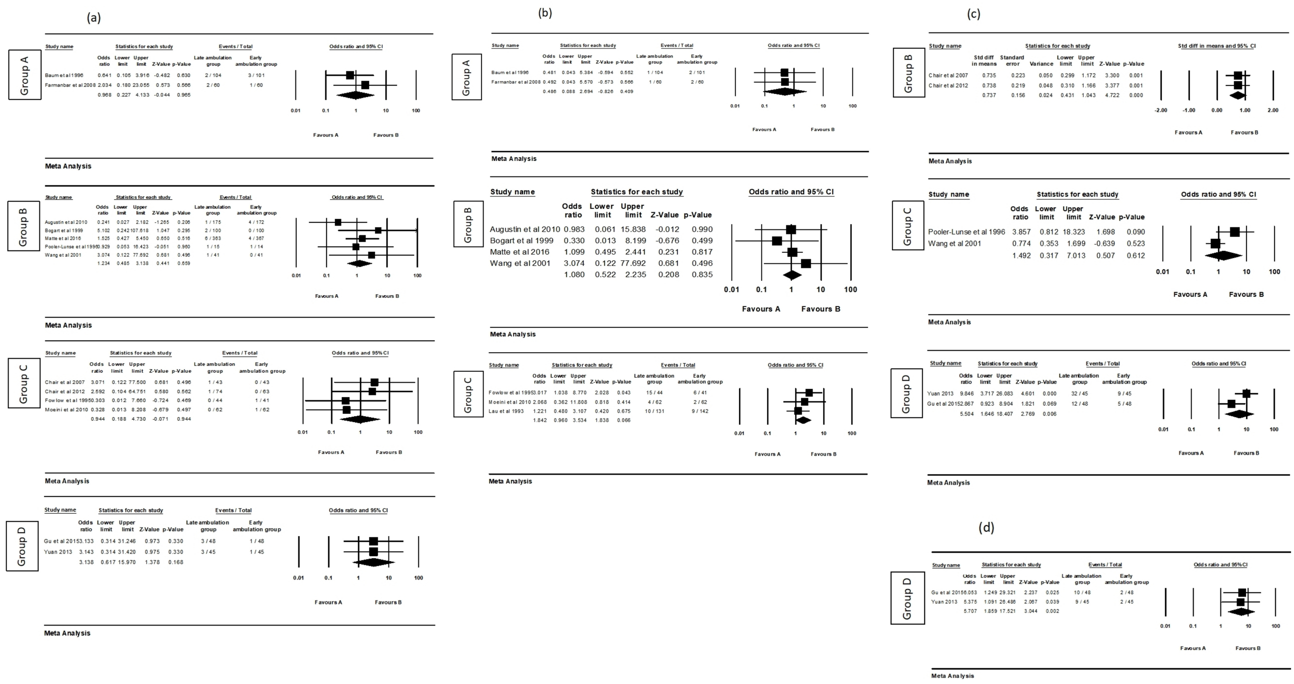

Fig. 5. Subgroup analysis to evaluate the effect of early mobilization. (a) Bleeding. (b) Hematoma. (c) Back pain. (d) Urinary retention. Group A, 2 h versus 4 h~6 h; Group B, 3 h~4 h versus 5 h~6 h; Group C, 4 h~6 h versus ≥8 h; Group D, 12 h versus 24 h. The horizontal lines denote the 95% CI, the Square (■) shows the point estimate (the size of the square corresponds to its weight); the diamond shows (◆) the combined overall effects of ambulation at 95% CI. CI, confidence interval.

were conducted in China and four in the USA. All studies except for one conducted by Gu *et al*. [48] reported two arms. Based on our subgroup rules, we only selectively extracted the data from two groups (ambulation after 12 h versus 24 h). Six studies [23,29,42,45,46,48] reported the indication for the cardiac catheterization, three for diagnosis [23,42,45] and three for therapy [29,46,48], respectively. Nine studies [23,29,40–43,46–48] used the manual compression method to obtain hemostasis, and a few studies employed additional methods such as bandage dressing or sandbags. Regarding heparin and sheath size, the usage regimen varied among the studies with some unavailable data. The characteristics are shown in Table 1 (Ref. [23,26,29,39–49]).

3.3 Critical Appraisal of the Included Studies

Two authors (JYW and SYT) independently judged the risk of bias. Overall, ten of the fourteen studies were ranked as "high risk" and only one randomized controlled trial (RCT) was rated as "low risk". Matte *et al*. [42] reported the research design and process according to all the domains of RoB 2, so we regarded this study as "low risk". Three RCTs were judged as having some concerns considering overall risk [23,40,41]. Patients were doomed to be instructed about resting duration due to the nature of the study design; therefore, allocation concealment could not be achieved. We did not perceive any studies as having a high blinding risk of bias for participants or the individuals delivering the interventions. All the studies reported that patients followed the bed rest instructions. But in the deviations from intended interventions domain, only one study was scored as "high risk" due to not conforming to the established hemostatic protocol [43]. In the missing outcome data domain, we rated one study by Moeini *et al*. [46] to be at "high risk" because of the vague reporting of the study results. Figs. 2,3 depict the assessment results.

3.4 The Effects of Early Mobilization on the Different Outcomes

We adopted a random effects analysis to assess the effect sizes. The forest plot showed the pooled effects of the six outcomes (bleeding, hematoma, back pain, pseudoaneurysm, urinary retention, and pain at the puncture site). In summary, six RCTs with a sample size of 569 found that the back pain of patients was significantly reduced by early mobilization (MD = 0.634, 95% CI: 0.23–1.038; p = 0.002). Nevertheless, early mobilization did not have any significant effects on bleeding (OR = 1.305, 95% CI: 0.683–2.494; p = 0.42), hematoma (OR = 1.328, 95% CI: 0.838–2.105; p = 0.227), pseudoaneurysm (OR = 1.442, 95% CI: 0.226–9.192; p = 0.698), urinary retention (OR = 2.62, 95% CI: 0.734–9.351; p = 0.138), and pain at the puncture site (MD = –0.019, 95% CI: –0.299–0.26; p = 0.892) among patients who underwent cardiac catheterization. The overall results of the meta-analysis are shown in Fig. 4.

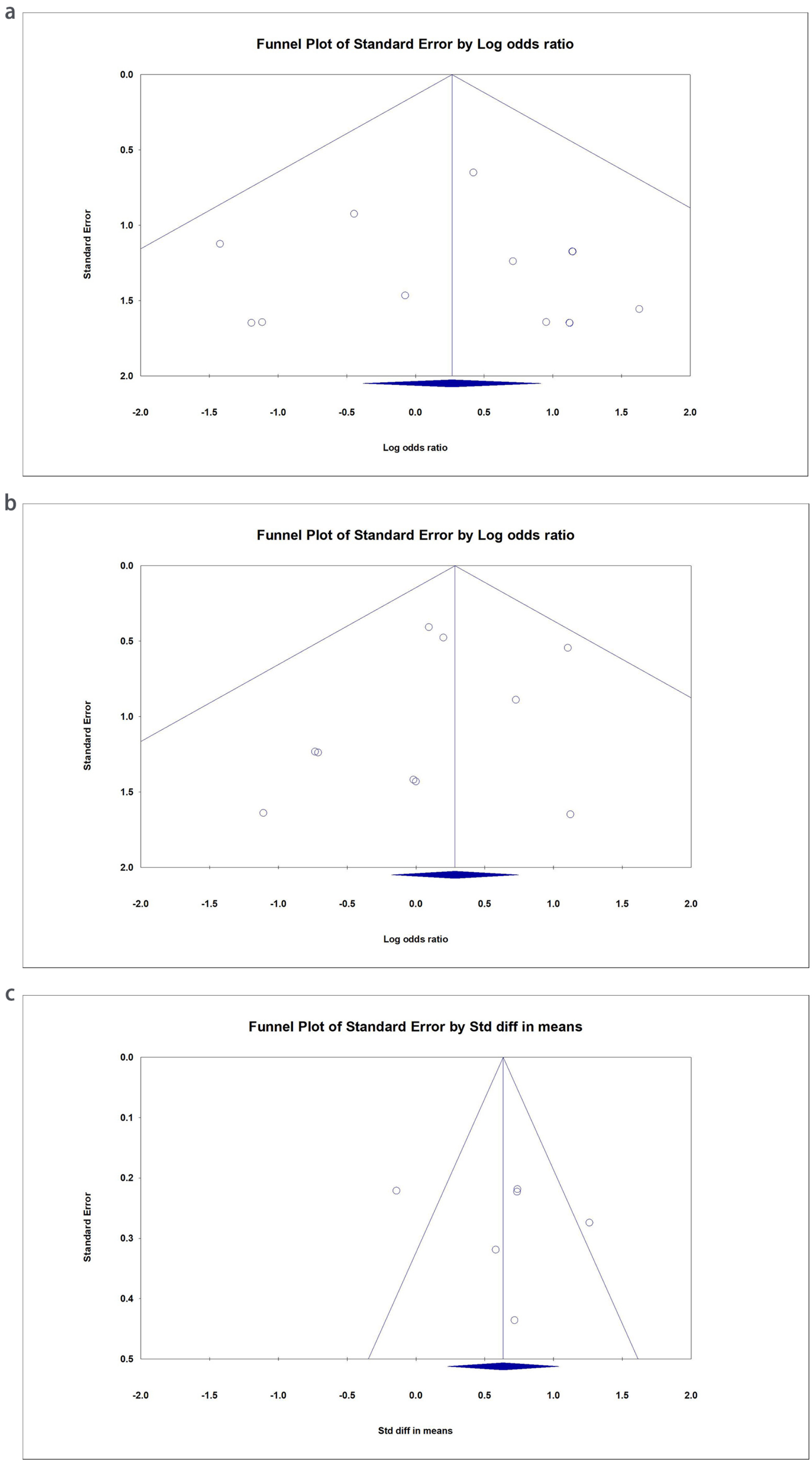

Fig. 6. Funnel plot to assess publication bias in the effects of early ambulation on different outcomes. (a) Bleeding. (b) Hematoma. (c) Back pain. Diagonal lines represent pseudo-95% confidence intervals. The y-axis represents the standard error (weight in the pooled analysis), the x-axis indicates the effect size, and the vertical line shows the calculated estimated effect of different outcomes.

Table 1. Summarized characteristics of the included studies.

Author (year) Country	Participants	Randomization method	Mean age IG	Mean age CG	Time to ambulation IG	Time to ambulation CG	Catheterization Type and sheath size	Heparin usage in the procedure	Hemostasis method	Outcomes
Augustin *et al*. (2010) [41] Brazil	TN = 347 CG: N = 175 IG: N = 172	Random computer-generated list	59.7 ± 9.9	61 ± 10.4	3 h postprocedure	6 h postprocedure	Elective PCI 6 F	Intravenous heparin in the dose of 100 UI/kg	Manual compression	①②④⑤⑦⑧
Baum *et al*. (1996) [39] USA	TN = 205 CG: N = 104 IG: N = 101	NA	58 ± 10	59 ± 10	2 h postprocedure	4 h postprocedure	Cardiac catheterization 5 F–8 F	IG: 94 UI CG: 96 UI	NA	①②
Chair *et al*. [26] (2007) Hong Kong China	TN = 86 CG: N = 43 IG: N = 43	Computer-generated random table of number	62.7 ± 9.7	63.2 ± 9.7	4 h postprocedure	12–24 h postprocedure	Elective cardiac catheterization NA	NA	NA	①②③⑨
Chair *et al*. (2012) [45] Hong Kong China	TN = 137 CG: N = 74 IG: N = 63	Computer-generated random list	NA	NA	4 h postprocedure	12–24 h postprocedure	Elective diagnostic cardiac catheterization NA	NA	NA	①②③⑨⑩⑪
Farmanbar *et al*. (2008) [40] Iran	TN = 120 CG: N = 60 IG: N = 60	NA	60.17 ± 11.5	59.9 ± 10.15	2 h postprocedure	6 h postprocedure	Angiography 7 F	NA	Manual compression + transparent dressing + sandbag	①②④⑫
Fowlow *et al*. (1995) [29] Canada	TN = 85 CG: N = 44 IG: N = 41	NA	MA of males: 54; MA of females: 61	MA of males: 58.2; MA of females: 63.9	6 h postprocedure	8 h postprocedure	Elective PTCA 7.5 F–9 F	Average usage was 10,125 UI	Manual compression + pressure dressing	①②⑫⑬
Bogart *et al*. (1999) [23] USA	TN = 200 CG: N = 100 IG: N = 100	NA	60 ± 10	55 ± 10	4 h postprocedure	6 h postprocedure	Diagnostic cardiac catheterization 8 F	NA	Manual compression	①②④⑫⑭⑮
Matte *et al*. (2016) [42] Brazil	TN = 730 CG: N = 363 IG: N = 367	Computer-generated random list	61.5 ± 11	63 ± 10	3 h postprocedure	5 h postprocedure	Diagnostic cardiac catheterization 6 F	NA	Manual compression	①②④⑥⑦⑳
Moeini *et al*. (2010) [46] Iran	TN = 124 CG: N = 62 IG: N = 62	Admission numbers	NA	NA	4 h postprocedure	8 h postprocedure	Angioplasty 7 F	72–100 UI/kg	Manual compression + sandbag	①②
Pooler-Lunse *et al*. (1996) [43] Canada	TN = 29 CG: N = 15 IG: N = 14	NA	60	64.6	4 h postprocedure	6 h postprocedure	Cardiac angiography 6 F–8 F	Heparin doses averaged between 900–1200 UI per hour	Manual compression + pressure dressing	①②③

Table 1. Continued.

Author (year) Country	Participants	Randomization method	Mean age IG	Mean age CG	Time to ambulation IG	Time to ambulation CG	Catheterization Type and sheath size	Heparin usage in the procedure	Hemostasis method	Outcomes
Wang *et al.* (2001) [44] USA	TN = 82 CG: N = 41 IG: N = 41	NA	58.7	62	4 h postprocedure	6 h postprocedure	Cardiac catheterization 5 F/6 F	NA	Sandbag + adhesive bandage	①②③⑥⑪⑯
Gu *et al.* (2015) [48] China	TN = 145 CG: N = 48 IG1: N = 49 IG2: N = 48	NA	IG1: 67 ± 10.5; IG2: 64.8 ± 11	65.2 ± 9.8	IG1: 18 h postprocedure IG2: 12 h postprocedure	24 h postprocedure	Therapeutic cardiac Catheterization 6 F	CG: 7177 ± 4234 UI IG1: 6306 ± 4432 UI IG2: 6865 ± 4544 UI	Manual compression + pressure dressing + sandbag	①③⑤⑦⑰
Yuan (2013) [49] China	TN = 90 CG: N = 45 IG: N = 45	NA	NA	NA	12 h postprocedure	24 h postprocedure	Cardiac catheterization	NA	Adhesive bandage + sandbag	①②③⑤⑱
Lau *et al.* (1993) [47] Singapore	TN = 273 CG: N = 131 IG: N = 142	National identity card numbers	53 ± 11	55 ± 11	6 h postprocedure	The following morning postprocedure	Cardiac catheterization 7 F	2000–2500 UI	Manual compression	②⑲

Notes: TN, total number; CG, control group; IG, intervention group; NA, not available; MA, mean age; ①, bleeding; ②, Hematoma; ③, back pain; ④, pseudoaneurysm; ⑤, urinary retention; ⑥, puncture-site pain; ⑦, vasovagal response; ⑧, lumbar pain; ⑨, urinary discomfort; ⑩, general well-being; ⑪, patient satisfaction; ⑫, arteriovenous fistula; ⑬, Pain perception; ⑭, limb ischemia; ⑮, thrombosis of the femoral artery; ⑯, numbness or tingling in affected leg; ⑰, anxiety; ⑱, insomnia; ⑲, allergy; ⑳, bruising; PCI, percutaneous coronary intervention; PTCA, percutaneous Transluminal Coronary Angioplasty; UI, units.

Table 2. The summary of publication bias results.

Outcomes	Bed rest duration group	Number of studies	Sample size	I^2 (%)	Egger's test	Begg's test
Bleeding	/	13	2380	0	0.831	0.714
	2 h versus 4 h~6 h	2	325	0	/	/
	3 h~4 h versus 5 h~6 h	5	1306	0	0.878	0.327
	4 h~6 h versus ≥8 h	4	432	0	0.914	0.497
	12 h versus 24 h	2	235	0	/	/
Hematoma	/	10	2256	0	0.415	0.788
	2 h versus 4 h~6 h	2	325	0	/	/
	3 h~4 h versus 5 h~6 h	4	1359	0	0.899	1
	4 h~6 h versus ≥8 h	3	482	0	0.781	0.602
Back pain	/	6	569	72.063	0.621	0.851
	3 h~4 h versus 5 h~6 h	2	111	69.263	/	/
	4 h~6 h versus ≥8 h	2	223	0	/	/
	12 h versus 24 h	2	235	61.813	/	/
Pseudoaneurysm	/	3	1277	0	0.941	0.602
Urinary retention	/	4	719	73.87	0.476	0.497
	12 h versus 24 h	2	235	0	/	/
Pain at the puncture site	/	2	812	21.31	/	/

3.5 Subgroup Analysis

Subgroup analyses were not possible owing to the lack of different bed rest duration groups concerning the outcome of pseudoaneurysm and pain at the puncture site. We only conducted subgroup analyses based on four outcomes: bleeding, hematoma, back pain, and urinary retention. The moderator variable was bed rest duration, including group A (2 h versus 4 h~6 h), group B (3 h~4 h versus 5 h~6 h), group C (4 h~6 h versus ≥8 h), and group D (12 h versus 24 h). Some subgroup analyses were unavailable because of the limited studies regarding different bed rest duration for each outcome.

We found the effect of patients' back pain were statistically significant when they were they had instruction for early mobilization in groups B (MD = 0.737, 95% CI: 0.431–1.043; p = 0.000) and D (OR = 5.504, 95% CI: 1.646–18.407; p = 0.006). The forest plot shows the patients' urinary retention was significantly decreased by early mobilization in group D (OR = 5.707, 95% CI: 1.859–17.521; p = 0.002). In contrast, early mobilization in group C (OR = 1.492, 95% CI: 0.317–7.013; p = 0.612) did not have an effect on the patients' back pain. As for outcomes of bleeding and hematoma, the results showed no statistical significance among all the bed rest duration groups. Fig. 5 shows the details of the subgroup analysis.

3.6 Sensitivity and Publication Bias

The I^2 index of the effects of early mobilization on bleeding (I^2 = 0%), hematoma (I^2 = 0%), pseudoaneurysm (I^2 = 0%), and pain at the puncture site (I^2 = 21.31%) did not reflect heterogeneity, whereas the results of back pain (I^2 = 72.06%) and urinary retention (I^2 = 73.99%) showed a moderate heterogeneity. The publication bias of included studies reporting bleeding, hematoma, and back pain could be estimated by funnel plots, as shown in Fig. 6. Random-effect models were used in the overall meta-analysis process due to insufficient studies regarding some outcomes. The p-value of Egger's test and Begg's test for the effect of bleeding (p-value = 0.831 for Egger's test and p-value = 0.714 for Begg's test), hematoma (p-value = 0.415 for Egger's test and p-value = 0.788 for Begg's test), back pain (p-value = 0.621 for Egger's test and p-value = 0.851 for Begg's test), pseudoaneurysm (p-value = 0.941 for Egger's test and p-value = 0.602 for Begg's test), and urinary retention (p-value = 0.476 for Egger's test and p-value = 0.497 for Begg's test) did not indicate significant publication bias. Still, the possibility of publication bias cannot be denied. As shown in Table 2.

4. Discussion

To the best of our knowledge, this study is the first systematic review involving both English and Chinese studies, using the information from 14 randomized controlled trials with 2653 participants, to assess the effect of early mobilization on patients' complications after trans-femoral cardiac catheterization. Nowadays, early mobilization is strongly recommended in to shorten the length of hospital stay and enhance recovery after surgery (ERAS) [50]. It has been associated with a reduced risk of insulin resistance, gastrointestinal complications, thromboembolism, and deconditioning of the cardiovascular, respiratory, and musculoskeletal systems, especially for elderly patients. However, the lack of a standard term for "early mobilization" may lead to delayed mobilization [51,52].

Our meta-analysis demonstrated that early mobilization of patients after cardiac catheterization via the femoral artery is practicable, and was associated with a lower incidence of back pain. That was in line with the two similar reviews by Mohammady *et al*. [24,53]. Prolonged supine bed rest causes pressure to be exerted continuously onto the same back muscle, which inevitably results in back pain [54]. However, early mobilization did not necessarily reduce the risk of urinary retention, pain at the puncture site, and vascular complications such as bleeding, hematoma, and pseudoaneurysm, which were relatively consistent with previous reviews [24,53,55,56]. It was confirmed that VCD were an effective hemostatic measure to prevent bleeding, surpassing manual compression and sandbags [57–59]. Even though the usage of VCD was ruled out from the study selection process, we still found early mobilization did not increase the risk of vascular complications at the puncture site. As opposed to our finding, a recent network meta-analysis conducted by Busca *et al*. [30] indicated a lower risk of hematoma at a shorter bed rest duration and a higher risk at a longer duration. That was surprising and not representative, as the effect on potential confounding variables of VCD may explain these findings. Traditional pressure dressing and manual compression, which can stretch across or circumferentially envelope the torso to constitute an absorbent layer over the sterile dressing sites by the elastic adhesive bandage, can press the dead space to reduce the risk of hematoma and seroma formation [60,61]. In contrast, the pressure of VCD is hard to measure and even causes damage to the puncture site which can accelerate the formation of a hematoma.

In this meta-analysis, we classified the bed rest duration into four categories (2 h versus 4 h~6 h, 3 h~4 h versus 5 h~6 h, 4 h~6 h versus ≥8 h, 12 h versus 24 h) in which the short bed rest duration was regarded as early mobilization in each category based on the comprehensive literature review, in summary, the early mobilization times varied from 2 h to 6 h except two studies happening in mainland China set as 12 h. The longer early mobilization time may result from the prudent notion of traditional Chinese culture and fewer attempts related to ERAS for Chinese cardiac catheterization patients. Our subgroup analysis results resembling previous reviews showed early mobilization significantly released back pain in the 3 h~4 h versus 5 h~6 h and 12 h versus 24 h categories and urinary retention in the 12 h versus 24 h category [24,53]. We found patient bed rests for 12 h related to a lower risk of urinary retention than bed rest for 24 h. That may be because longer resting time in bed results in lower neuronal output activities from the same sacral roots as the bladder and lower limbs [62].

Cardiac catheterization, routinely using heparin and aspirin directed by the managing clinician, has the risk of vascular complications. As is reported, lower heparin doses, such as 25 UI/kg/h, have an apparent half-life of 30 minutes, whereas higher doses of 100 and 400 UI/kg/h are associated with half-lives of 60 minutes and 150 minutes, respectively [63]. Combining the results of this meta-analysis, we suggested patients who underwent trans-femoral cardiac catheterization could mobilize after 2 h~4 h bed rest for the sake of safety and comfort.

In a word, we perceived all the included 14 studies as a moderate to low heterogeneity because the I^2 index depicted in Table 2 were lower than 75%, which suggested our findings could be regarded as robust. But some statistically significant results from subgroup analysis regarding back pain and urinary retention outcomes should be assumed to be overweighted because of the limited numbers and data from the same research team. In addition, two eligible Chinese mainland randomized controlled trials enriched the sources of evidence compared to previous studies, resulting in not only the credibility of the conclusion being highlighted but the applicability of the findings being more extensive.

5. Limitations

Our study has some limitations. Firstly, the definition of bleeding, hematoma formation, pseudoaneurysm, and urinary retention varied among studies, and pain is a self-perceived experience. It may lower our confidence in the results with the increasing risk of heterogeneity. Secondly, the small number of studies gave us less access to fully evaluate the effect of early mobilization on patients' complication outcomes, especially specifying the reliable effect on some outcomes based on different bed rest duration is impossible. Finally, we could not conduct a more comprehensive subgroup analysis with incomplete information on heparin usage and sheath sizes from original studies. We could only infer that all the included studies adopted hemostasis protocols, whether they are well-standardized protocols is not able to confirm. They are also sources of heterogeneity. Further well-designed study is needed, and the findings of our meta-analysis should be interpreted with caution.

6. Conclusions

In conclusion, the findings from our meta-analysis approved the current proposition that shortening bed rest duration is beneficial to patients who have undergone cardiac catheterization trans-femoral artery; it is possible to underscore the safety and effectiveness of early mobilization after 2 h~4 h bed rest without more risk of vascular complications and discomfort. Even if the benefits of early mobilization are considered to be beyond the perceived risks, significant barriers, including fears of vascular complications and the complexity of the specific surgical site, can interfere with its proceeding [64]. According to the reality and circumstances of different surgical sites, the perspectives and initiatives on positively helping patients move early based on the convincing evidence are the beginning of the continued success of ERAS.

Availability of Data and Materials

All data points generated or analyzed during this study are included in this article and there are no further underlying data necessary to reproduce the results.

Author Contributions

YB, ZLC, and JYW conceived and designed the study. JYW, JC and SYT performed data retrieval and data extraction, methodological quality evaluation, and risk of bias assessment; YW, LHZ, YB and ZLC were invited to discuss discrepancies; they curated the data and supervised the study; QL was responsible for software usage and performed the meta-analysis process; JYW and JC drafted the manuscript. YW, LHZ, SYT and QL reviewed and edited the manuscript. All authors had reviewed and approved the final version of the manuscript. They had full access to all the data of this study. All authors contributed to editorial changes in the manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

All contents and methods were approved by the ethics committee of West China Hospital, Sichuan University (2021, Review No. 591).

Acknowledgment

Not applicable.

Funding

The meta-analysis was supported by the "Natural Science Foundation of Sichuan Province (grant number 2022NSFSC0645)", and the "Natural Science Foundation of Sichuan Province (grant number 2023YFQ0099)".

Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.31083/j.rcm2505152.

References

[1] Kosova E, Ricciardi M. Cardiac Catheterization. Journal of the American Medical Association. 2017; 317: 2344.
[2] Rao SV, Stone GW. Arterial access and arteriotomy site closure devices. Nature Reviews. Cardiology. 2016; 13: 641–650.
[3] Ludman PH. On behalf of the British Cardiovascular Intervention Society. BCIS Audit Returns: Adult Intervention Procedures. 2013. Available at: http://www.bcis.org.uk/documents/BCIS_Audit_2014_07102015_for_web.pdf (Accessed: 14 January 2016).
[4] Tsao CW, Aday AW, Almarzooq ZI, Alonso A, Beaton AZ, Bittencourt MS, *et al*. Heart Disease and Stroke Statistics-2022 Update: A Report From the American Heart Association. Circulation. 2022; 145: e153–e639.
[5] The Writing Committee of the Report on Cardiovascular Health and Diseases in China. Key points of Report on Cardiovascular Health and Diseases in China 2021. Chinese Journal of Cardiovascular Research. 2022; 20: 577–596. (In Chinese)
[6] Chiarito M, Cao D, Nicolas J, Roumeliotis A, Power D, Chandiramani R, *et al*. Radial versus femoral access for coronary interventions: An updated systematic review and meta-analysis of randomized trials. Catheterization and Cardiovascular Interventions: Official Journal of the Society for Cardiac Angiography & Interventions. 2021; 97: 1387–1396.
[7] Anjum I, Khan MA, Aadil M, Faraz A, Farooqui M, Hashmi A. Transradial vs. Transfemoral Approach in Cardiac Catheterization: A Literature Review. Cureus. 2017; 9: e1309.
[8] Webb JG, Wood DA. Current status of transcatheter aortic valve replacement. Journal of the American College of Cardiology. 2012; 60: 483–492.
[9] Kussmaul WG, 3rd, Buchbinder M, Whitlow PL, Aker UT, Heuser RR, King SB, *et al*. Rapid arterial hemostasis and decreased access site complications after cardiac catheterization and angioplasty: results of a randomized trial of a novel hemostatic device. Journal of the American College of Cardiology. 1995; 25: 1685–1692.
[10] Benson G. Changing patients' position in bed after non-emergency coronary angiography reduced back pain. Evidence-based Nursing. 2004; 7: 19.
[11] Roebuck A, Jessop R, Turner R, Caplin JL. The safety of two-hour versus four-hour bed rest after elective 6-french femoral cardiac catheterization. Coronary Health Care. 2000; 4: 169–173.
[12] Beattie S. Cut the risks for cardiac cath patients. RN. 1999; 62: 50–54; quiz 55.
[13] Babb T, Levine B, Philley J. ICU-acquired weakness: an extension of the effects of bed rest. American Journal of Respiratory and Critical Care Medicine. 2012; 185: 230–231.
[14] Cameron S, Ball I, Cepinskas G, Choong K, Doherty TJ, Ellis CG, *et al*. Early mobilization in the critical care unit: A review of adult and pediatric literature. Journal of Critical Care. 2015; 30: 664–672.
[15] Perme C, Chandrashekar R. Early mobility and walking program for patients in intensive care units: creating a standard of care. American Journal of Critical Care: an Official Publication, American Association of Critical-Care Nurses. 2009; 18: 212–221.
[16] Chappell D, Jacob M. Influence of non-ventilatory options on postoperative outcome. Best Practice & Research. Clinical Anaesthesiology. 2010; 24: 267–281.
[17] Needham DM, Korupolu R, Zanni JM, Pradhan P, Colantuoni E, Palmer JB, *et al*. Early physical medicine and rehabilitation for patients with acute respiratory failure: a quality improvement project. Archives of Physical Medicine and Rehabilitation. 2010; 91: 536–542.
[18] Lundén MH, Bengtson A, Lundgren SM. Hours during and after coronary intervention and angiography. Clinical Nursing Research. 2006; 15: 274–289.
[19] Schiks IEJM, Schoonhoven L, Aengevaeren WRM, Nogarede-Hoekstra C, van Achterberg T, Verheugt FWA. Ambulation after femoral sheath removal in percutaneous coronary intervention: a prospective comparison of early vs. late ambulation. Journal of Clinical Nursing. 2009; 18: 1862–1870.
[20] Kanejima Y, Shimogai T, Kitamura M, Ishihara K, Izawa KP. Effect of Early Mobilization on Physical Function in Patients after Cardiac Surgery: A Systematic Review and Meta-Analysis. International Journal of Environmental Research and Public Health. 2020; 17: 7091.
[21] Adler J, Malone D. Early mobilization in the intensive care unit: a systematic review. Cardiopulmonary Physical Therapy Journal. 2012; 23: 5–13.
[22] Jones RA, Merkle S, Ruvalcaba L, Ashton P, Bailey C, Lopez M. Nurse-Led Mobility Program: Driving a Culture of Early Mobilization in Medical-Surgical Nursing. Journal of Nursing Care Quality. 2020; 35: 20–26.

[23] Bogart MA, Bogart DB, Rigden LB, Jung SC, Liston MJ. A prospective randomized trial of early ambulation following 8 French diagnostic cardiac catheterization. Catheterization and Cardiovascular Interventions: Official Journal of the Society for Cardiac Angiography & Interventions. 1999; 47: 175–178.
[24] Mohammady M, Heidari K, Akbari Sari A, Zolfaghari M, Janani L. Early ambulation after diagnostic transfemoral catheterisation: a systematic review and meta-analysis. International Journal of Nursing Studies. 2014; 51: 39–50.
[25] Doyle BJ, Konz BA, Lennon RJ, Bresnahan JF, Rihal CS, Ting HH. Ambulation 1 hour after diagnostic cardiac catheterization: a prospective study of 1009 procedures. Mayo Clinic Proceedings. 2006; 81: 1537–1540.
[26] Chair SY, Thompson DR, Li SK. The effect of ambulation after cardiac catheterization on patient outcomes. Journal of Clinical Nursing. 2007; 16: 212–214.
[27] Gall S, Tarique A, Natarajan A, Zaman A. Rapid ambulation after coronary angiography via femoral artery access: a prospective study of 1,000 patients. The Journal of Invasive Cardiology. 2006; 18: 106–108.
[28] Nørgaard MW, Færch J, Joshi FR, Høfsten DE, Engstrøm T, Kelbæk H. Is It Safe to Mobilize Patients Very Early After Transfemoral Coronary Procedures? (SAMOVAR): A Randomized Clinical Trial. The Journal of Cardiovascular Nursing. 2022; 37: E114–E121.
[29] Fowlow B, Price P, Fung T. Ambulation after sheath removal: a comparison of 6 and 8 hours of bedrest after sheath removal in patients following a PTCA procedure. Heart & Lung: the Journal of Critical Care. 1995; 24: 28–37.
[30] Busca E, Airoldi C, Bertoncini F, Buratti G, Casarotto R, Gaboardi S, *et al*. Bed rest duration and complications after transfemoral cardiac catheterization: a network meta-analysis. European Journal of Cardiovascular Nursing. 2023; 22: 454–462.
[31] Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, *et al*. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. Journal of Clinical Epidemiology. 2021; 134: 178–189.
[32] Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. Journal of Clinical Epidemiology. 2009; 62: 1006–1012.
[33] Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JPA, *et al*. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Annals of Internal Medicine. 2009; 151: W65–W94.
[34] Sterne JAC, Savović J, Page MJ, Elbers RG, Blencowe NS, Boutron I, *et al*. RoB 2: a revised tool for assessing risk of bias in randomised trials. BMJ (Clinical Research Ed.). 2019; 366: l4898.
[35] Higgins JPT, Green S. Cochrane Handbook for Systematic Reviews of Interventions, version 5.1.0 (updated March 2011). The Cochrane Collaboration. 2011. Available at: http://handbook-5-1.cochrane.org (Accessed: 23 December 2012).
[36] Egger M, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ (Clinical Research Ed.). 1997; 315: 629–634.
[37] Begg CB, Mazumdar M. Operating characteristics of a rank correlation test for publication bias. Biometrics. 1994; 50: 1088–1101.
[38] Cohen J. Statistical Power Analysis for the Behavioral Sciences. Revised edition. Academic Press: New York, NY, USA. 1997.
[39] Baum RA, Gantt DS. Safety of decreasing bedrest after coronary angiography. Catheterization and Cardiovascular Diagnosis. 1996; 39: 230–233.
[40] Farmanbar R, Chinikar M, Gozalian M, Baghaie M, Moghadamnia M. The effect of post coronary angiography bed-rest time on vascular complications. Journal of Tehran University Heart Center. 2008; 3: 225–228.
[41] Augustin AC, de Quadros AS, Sarmento-Leite RE. Early sheath removal and ambulation in patients submitted to percutaneous coronary intervention: a randomised clinical trial. International Journal of Nursing Studies. 2010; 47: 939–945.
[42] Matte R, Hilário TDS, Reich R, Aliti GB, Rabelo-Silva ER. Reducing bed rest time from five to three hours does not increase complications after cardiac catheterization: the THREE CATH Trial. Revista Latino-americana De Enfermagem. 2016; 24: e2796.
[43] Pooler-Lunse C, Barkman A, Bock BF. Effects of modified positioning and mobilization of back pain and delayed bleeding in patients who had received heparin and undergone angiography: a pilot study. Heart & Lung: the Journal of Critical Care. 1996; 25: 117–123.
[44] Wang SL, Redeker NS, Moreyra AE, Diamond MR. Comparison of comfort and local complications after cardiac catheterization. Clinical Nursing Research. 2001; 10: 29–39.
[45] Chair SY, Yu M, Choi KC, Wong EML, Sit JWH, Ip WY. Effect of early ambulation after transfemoral cardiac catheterization in Hong Kong: a single-blinded randomized controlled trial. Anadolu Kardiyoloji Dergisi: AKD = the Anatolian Journal of Cardiology. 2012; 12: 222–230.
[46] Moeini M, Moradpour F, Babaei S, Rafieian M, Khosravi A. Four hour ambulation after angioplasty is a safe practice method. Iranian Journal of Nursing and Midwifery Research. 2010; 15: 109–114.
[47] Lau KW, Tan A, Koh TH, Koo CC, Quek S, Ng A, *et al*. Early ambulation following diagnostic 7-French cardiac catheterization: a prospective randomized trial. Catheterization and Cardiovascular Diagnosis. 1993; 28: 34–38.
[48] Gu J, Shi DM, Xu YL, Jiang HF. Discussion on sandbag compression time and bed rest time after PCI via femoral artery. Journal of Nurses Training. 2015; 30: 2090–2091. (In Chinese)
[49] Yuan JD. The nursing intervention of the early immobilization time and position after PCI procedure bypass femoral artery. Journal of Qiqihar University of Medicine. 2013; 34: 1991–1992. (In Chinese)
[50] Ljungqvist O, Scott M, Fearon KC. Enhanced Recovery After Surgery: A Review. JAMA Surgery. 2017; 152: 292–298.
[51] Hashem MD, Parker AM, Needham DM. Early Mobilization and Rehabilitation of Patients Who Are Critically Ill. Chest. 2016; 150: 722–731.
[52] Tazreean R, Nelson G, Twomey R. Early mobilization in enhanced recovery after surgery pathways: current evidence and recent advancements. Journal of Comparative Effectiveness Research. 2022; 11: 121–129.
[53] Mohammady M, Atoof F, Sari AA, Zolfaghari M. Bed rest duration after sheath removal following percutaneous coronary interventions: a systematic review and meta-analysis. Journal of Clinical Nursing. 2014; 23: 1476–1485.
[54] Burn KL, Marshall B, Scrymgeour G. Early mobilization after femoral approach diagnostic coronary angiography to reduce back pain. Journal of Radiology Nursing. 2015; 34: 162–169.
[55] Kim K, Won S, Kim J, Lee E, Kim K, Park S. Meta-analysis of complication as a risk factor for early ambulation after percutaneous coronary intervention. European Journal of Cardiovascular Nursing. 2013; 12: 429–436.
[56] Logemann T, Luetmer P, Kaliebe J, Olson K, Murdock DK. Two versus six hours of bed rest following left-sided cardiac catheterization and a meta-analysis of early ambulation trials. The American Journal of Cardiology. 1999; 84: 486–488, A410.
[57] Marso SP, Amin AP, House JA, Kennedy KF, Spertus JA, Rao

SV, *et al*. Association between use of bleeding avoidance strategies and risk of periprocedural bleeding among patients undergoing percutaneous coronary intervention. JAMA. 2010; 303: 2156–2164.
[58] Schulz-Schüpke S, Helde S, Gewalt S, Ibrahim T, Linhardt M, Haas K, *et al*. Comparison of vascular closure devices vs manual compression after femoral artery puncture: the ISAR-CLOSURE randomized clinical trial. JAMA. 2014; 312: 1981–1987.
[59] Pang N, Gao J, Zhang B, Guo M, Zhang N, Sun M, *et al*. Vascular Closure Devices versus Manual Compression in Cardiac Interventional Procedures: Systematic Review and Meta-Analysis. Cardiovascular Therapeutics. 2022; 2022: 8569188.
[60] Kaimal A, Philip J, Greenberg J. How Much Pressure Does a Pressure Dressing Press? A Pilot Study Quantifying the Effects of a Pressure Dressing on the Post-Cesarean Section Incision. Wounds Research. 2020. Available at: https://www.woundsresearch.com/article/5468 (Accessed: 10 July 2020).
[61] Mehta NK, Doerr K, Skipper A, Rojas-Pena E, Dixon S, Haines DE. Current strategies to minimize postoperative hematoma formation in patients undergoing cardiac implantable electronic device implantation: A review. Heart Rhythm. 2021; 18: 641–650.
[62] Rodrigues P, Hering F, Cieli E, Campagnari JC. Rate of spontaneous voiding recovery after acute urinary retention due to bed rest in the hospital setting in a nonurological population clinical study of the relationship between lower limbs and bladder function. International Braz J Urol: Official Journal of the Brazilian Society of Urology. 2016; 42: 1202–1209.
[63] Hirsh J, Warkentin TE, Raschke R, Granger C, Ohman EM, Dalen JE. Heparin and low-molecular-weight heparin: mechanisms of action, pharmacokinetics, dosing considerations, monitoring, efficacy, and safety. Chest. 1998; 114: 489S–510S.
[64] Fontela PC, Forgiarini LA, Jr, Friedman G. Clinical attitudes and perceived barriers to early mobilization of critically ill patients in adult intensive care units. Revista Brasileira De Terapia Intensiva. 2018; 30: 187–194.