

围手术期低吸入氧浓度减少腹部手术患者术后肺不张：一项系统评价和Meta分析

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摘 要

目的: 明确围手术期吸入氧浓度(FiO_2)与腹部手术后肺不张的关系。方法: 检索PubMed、Cochrane图书馆、Embase和Web of Science数据库, 寻找报道全麻围手术期 FiO_2 影响腹部手术患者术后肺不张的随机对照试验。我们使用随机效应模型来计算这些术后肺不张发生率的相对风险。根据年龄、通气策略、手术切口部位、手术时间进行亚组分析。结果: 最后, 我们纳入了9项随机对照试验, 共3391名参与者。与高 FiO_2 相比(60%~100%), 低 FiO_2 (30%~40%)患者腹部手术后肺不张的发生率降低。与60岁以下的患者相比, 平均年龄大于60岁的患者, 围术期采用低 FiO_2 可以预防术后肺不张[RR: 1.64; 95%CI: 1.31~2.06]。接受下腹部手术的患者, 围术期采用低 FiO_2 可以预防术后肺不张[RR: 1.63; 95%CI: 1.27~2.08]。结论: 本研究提示围手术期低 FiO_2 降低下腹手术患者术后肺不张的风险, 此作用在平均年龄小于60岁的患者中尤为明显。

关键词

腹部手术, 全身麻醉, 氧气, 术后肺不张

Perioperative Low Fraction of Inspired Oxygen Reduces Postoperative Atelectasis in Abdominal Surgery Patients: A Systematic Review and Meta-Analysis

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Abstract

Objective: To clarify the relationship between the perioperative fraction of inspired oxygen (FiO_2) and postoperative atelectasis after abdominal surgery. **Methods:** We searched the PubMed, Cochrane Library, Embase, and Web of Science databases for randomized controlled trials (RCTs) reporting the effect of perioperative FiO_2 under general anesthesia on postoperative atelectasis in patients undergoing abdominal surgery. We used a random-effects model to calculate the relative risk (RR) for the incidence of postoperative atelectasis. Subgroup analyses were conducted based on patient age, ventilation strategies, surgical incision site, and duration of surgery. **Results:** Nine RCTs, involving a total of 3391 participants, were included in the final analysis. Compared to high FiO_2 (60%~100%), the use of low FiO_2 (30%~40%) was associated with a reduced incidence of postoperative atelectasis following abdominal surgery. In patients with a mean age greater than 60 years, the use of perioperative low FiO_2 demonstrated a preventive effect against postoperative atelectasis [RR: 1.64; 95%CI: 1.31~2.06] when compared to patients < 60 years. Similarly, the use of perioperative low FiO_2 was associated with the prevention of postoperative atelectasis in patients undergoing lower abdominal surgery [RR: 1.63; 95%CI: 1.27~2.08]. **Conclusion:** This study suggests that perioperative low FiO_2 reduces the risk of postoperative atelectasis in patients undergoing lower abdominal surgery. This beneficial effect appears particularly pronounced in patients with a mean age younger than 60 years.

Keywords

Abdominal Surgery, General Anesthesia, Oxygen, Postoperative Atelectasis

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1. 介绍

肺不张出现在大多数接受全麻手术的患者,可持续数月之久[1]-[4]。特别是在腹部手术中,手术操作可向头端移动膈肌,降低肺顺应性,从而使腹部手术后肺不张的发生率较高[5]-[8]。肺不张的形成可能有三种机制:气体吸收、肺组织压缩和表面活性剂缺乏[2]。此外,肺不张被认为是一些术后并发症的主要原因,如肺炎和低氧血症,这对患者的术后恢复是不利的。

目前,临床上经常通过提高吸入气氧浓度来提高动脉血氧分压[2] [9]-[14]。然而,关于围手术期 FiO_2 与术后肺不张之间的关系仍然存在着争议[15]-[18]。围手术期高 FiO_2 是否有利于预防腹部手术患者术后肺不张,在临床工作中仍存在争议。2019年发布的一项关于预防术后肺部并发症的专家共识提出,术中推荐 $\text{FiO}_2 \leq 40\%$ [19]。2020年, Li 等人发现,与较高的 FiO_2 相比,术中低 FiO_2 并没有降低接受腹部手术患者术后肺不张的发生率[15]。而 Park 等人反驳了上述结论,他们认为围手术期高 FiO_2 会导致腹部手术患者术后肺不张[16]。一方面,围手术期高 FiO_2 可以提高患者对缺氧和长时间呼吸暂停的耐受性[16]。另一方面,据报道,围手术期高 FiO_2 可以提高肺不张的发生率[2] [9] [20]。

因此,现迫切需要对腹部手术患者围手术期 FiO_2 与术后肺不张之间关系的现有证据进行综合评估。我们的目的是从比较腹部手术患者围手术期高 FiO_2 和低 FiO_2 对术后肺不张的影响的随机对照试验中提取相关数据,进行 Meta 分析,以确定围手术期 FiO_2 与腹部手术患者术后肺不张之间的关系。

2. 材料和方法

该 Meta 分析已在 PROSPERO 网站上注册,注册号为 CRD42021270703。我们根据系统评价和 Meta 分析首选报告项目规则(PRISMA)进行系统评价和 Meta 分析[21]。

2.1. 检索策略

在 PubMed、Cochrane 图书馆、Embase 和 Web of Science 数据库中全面检索了 2023 年 3 月之前发表的关于围手术期 FiO_2 影响患者腹部手术后肺不张的随机对照临床试验。此外,我们也对所有纳入研究的参考文献列表进行了检索。每个数据库的详细检索策略都呈现在补充材料中(表 S1)。

2.2. 纳入和排除标准

纳入的文献必须符合以下标准:1) 为随机对照试验;2) 调查了围手术期 FiO_2 对腹部手术后肺不张的影响;3) 患者为成人(18 岁及以上)。围手术期高 FiO_2 定义为: $\text{FiO}_2 \geq 50\%$,围手术期低 FiO_2 定义为: $\text{FiO}_2 < 50\%$ 。

排除标准包括:1) 综述、会议摘要、病例报告或动物实验研究;2) 接受区域麻醉手术的患者;3) 仅术后或术中短时间内接受吸氧的患者;4) 入住重症监护病房的患者。

2.3. 数据提取

根据我们制定的纳入排除标准,两位作者独立筛选文章标题和摘要,使用 Cochrane 协作工具评估偏倚风险[22],并从最终纳入的研究中根据预先制定的计划提取数据,两位作者遇到任何分歧时将通过协商来达成一致。需要提取的数据包括纳入研究的特征(第一作者、国家、出版年份、样本量、年龄)、干预策略和结果(术后肺不张的发生率、术后肺不张的严重程度)。我们采用相关公式将数据从中位数(四分位数间距)形式转化为平均值 $\pm$ 标准差的形式[23]。采用 Wilcox 严重程度评分和肺超声评分系统[24][25]评估术后肺不张的严重程度。

2.4. 数据整合

我们使用 RevMan 5.4 进行 Meta 分析。二分类变量以风险比(RRs)和 95%置信区间表示,而连续变量以均数差值(MD)和 95%置信区间的形式描述。采用 Cochran Q 检验和 Higgins I^2 检验来评估异质性并整合数据。如果 $0\% \leq I^2 < 25\%$,结果显示无异质性;如果为 $25\% \leq I^2 < 50\%$,结果显示低水平的异质性;如果 $50\% \leq I^2 < 75\%$,结果显示中等水平的异质性;如果是 $75\% \leq I^2 \leq 100\%$,结果显示出高水平的异质性。根据可能导致术后肺不张的危险因素(通气策略、给氧策略、年龄、手术时间、手术切口部位)进行亚组分析。此外,敏感性分析通过排除特定的研究来寻找异质性的来源。

3. 结果

3.1. 研究选择

我们检索到 2344 项研究,其中 966 项研究是重复的,筛选标题和摘要后排除了 1352 项研究。然后,我们进一步筛选了 26 篇文章的全文,其中 9 篇因缺乏结果而被排除,8 篇因报道非腹部手术而被排除。最后,有 9 项研究符合纳入标准[15][16][26]-[32](图 1)。所纳入研究的特征见表 1。

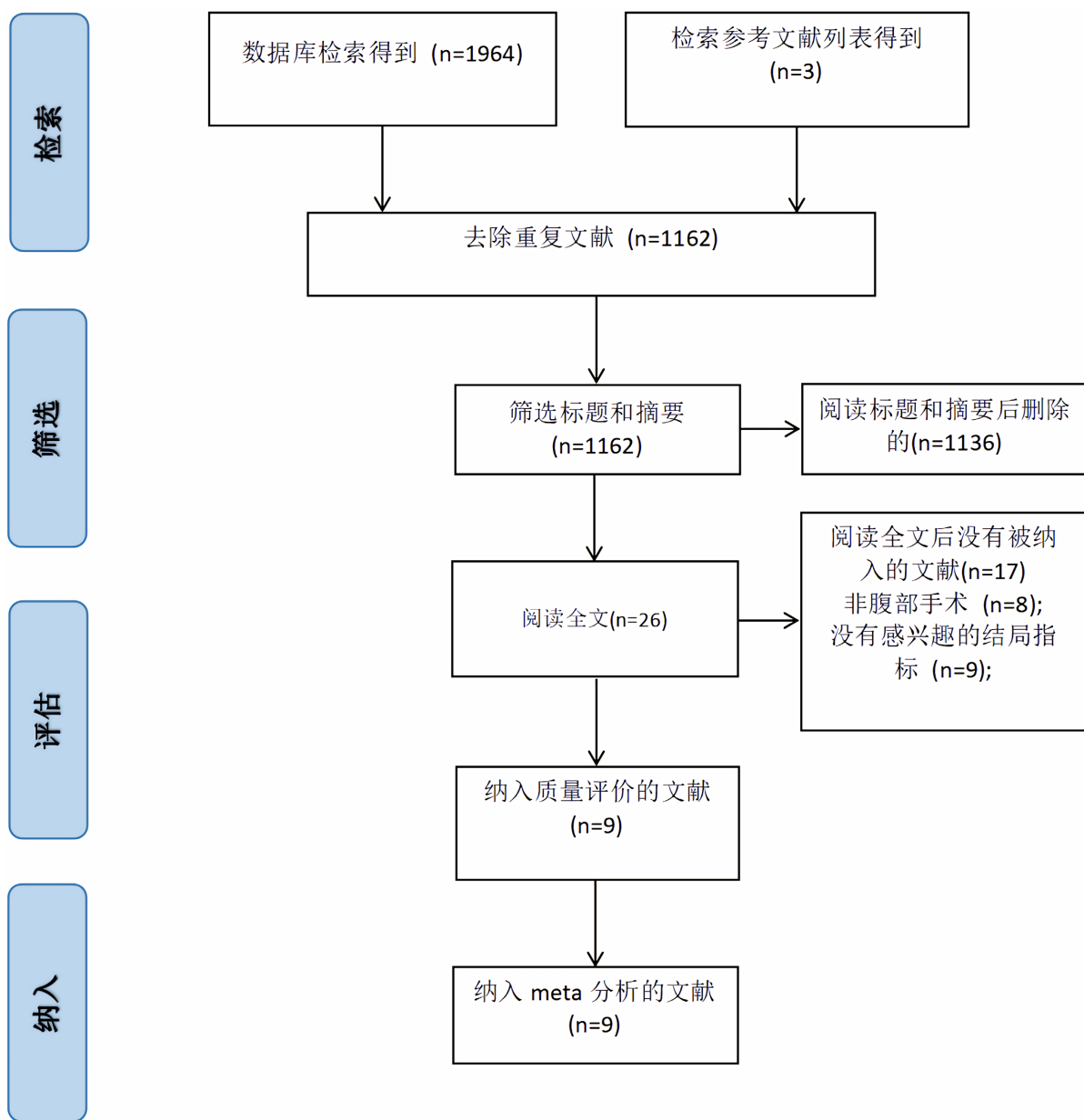


Figure 1. Literature screening flow diagram

图 1. 文献筛选流程图

Table 1. Characteristics of included studies
表 1. 纳入文献的特征

研究名称	国别	样本量 (高FiO ₂ / 低FiO ₂)	年龄 (岁)		FiO ₂	干预策略	呼气末 正压	结局检测	麻醉维持	手术类型	手术 部位	手术时长 (分钟)		麻醉时长 (分钟)	
			高FiO ₂	低FiO ₂								高FiO ₂	低FiO ₂	高FiO ₂	低FiO ₂
Lin et al 2021	中国	316/314	71.45 ± 3.85	71.39 ± 2.80	术中	术中	无	术后7天, 超声 检测	静脉或者 吸入	择期 + 急诊	腹腔镜	188.2 ± 12.7	188.7 ± 8.6	224.4 ± 5.0	224.3 ± 5.2
Park et al 2021	韩国	87/85	65 ± 23	66 ± 24	术中	术中	5 cmH ₂ O	术后2天, 超声 检测	静脉或者 吸入	择期	腹腔镜 + 开 腹	无	无	无	无
Li et al 2020	中国	126/125	54 ± 14	53 ± 13	术中	术中	6 cmH ₂ O ~ 8 cmH ₂ O	术后7天, X光 或CT检测	静脉或者 吸入	择期	腹腔镜 + 开 腹	196.7 ± 68.2	201.4 ± 84.0	257.1 ± 63.7	273.5 ± 85.5
Kim et al 2020	韩国	46/44	53 ± 14	51 ± 12	术中	术中	5 cmH ₂ O	术后PACU中, 超声检测	静脉	择期	腹腔镜	130.3 ± 72.7	103.5 ± 53.6	171.8 ± 88.0	150.3 ± 67.4
Ferrando et al 2020	国际多 中心	362/355	64.2 ± 12.8	63.9 ± 13.9	术中 + 术后 3小时	术中 + 术后 3小时	个体化 PEEP	术后7天, 超声 或CT检测	静脉或者 吸入	择期	腹腔镜 + 开 腹	214.2 ± 93.3	209.2 ± 89.7	无	无
Alvandipour et al 2019	伊朗	40/40	58.4 ± 8.1	59.2 ± 9.2	术中 + 术后 1小时	术中 + 术后 1小时	无	出院前X-光或 CT	吸入	择期	开腹	无	无	无	无
Staehr et al 2012	丹麦	20/15	64 ± 13	59 ± 16	术中 + 术后 2小时	术中 + 术后 2小时	5 cmH ₂ O	术后14天, X光或CT检测	静脉或者 吸入	择期	开腹	无	无	177.7 ± 110.1	202.2 ± 116.1
Meyhoff et al 2009	丹麦	685/701	58 ± 43	60 ± 37	术中 + 术后 2小时	术中 + 术后 2小时	无	术后14天, X光或CT检测	静脉或者 吸入	择期 + 急诊	开腹	160.2 ± 202.1	155.1 ± 193.1	221.5 ± 237.7	214.6 ± 219.9
Akca et al 1999	丹麦	685/701	49 ± 14	41 ± 10	术中 + 术后 2小时	术中 + 术后 2小时	无	术后1天, X光 或CT检测	吸入	择期	无	198 ± 60	168 ± 60	无	无

3.2. 研究质量和偏倚风险

偏倚评估的风险汇总见图 2 和图 S1。在 4 项研究[16] [27] [28] [30]中观察到执行偏倚的高风险，因为这些研究中的麻醉医师对于患者的 FiO_2 并未设盲，他们在术中对 FiO_2 水平进行适当的调整，以维持患者生命体征稳定。有三项研究没有描述被分配到相应研究组的麻醉医师和参与者是否知道分组情况[26] [29] [31]。其余两项研究中的麻醉医师对试验也未设盲[15] [32]，但他们没有参与到研究中，因此执行偏倚评分为低风险。

	Alvandipour et al 2019	Ferrando et al 2020	Kim et al 2020	Li et al 2020	Lin et al 2021	Meyhoff et al 2009	Park et al 2021	Staehr et al 2012	
Random sequence generation (selection bias)	+	+	+	+	+	+	+	+	
Allocation concealment (selection bias)	+	+	+	+	+	+	+	+	
Blinding of participants and personnel (performance bias)	+	+	?	+	+	?	+	+	
Blinding of outcome assessment (detection bias)	+	+	+	+	+	+	+	+	
Incomplete outcome data (attrition bias)	+	+	+	+	+	+	+	+	
Selective reporting (reporting bias)	+	+	+	+	+	+	+	+	
Other bias	+	+	+	+	+	+	+	+	

Figure 2. Risk of bias assessment table
图 2. 风险偏倚评估表

3.3. 结果

纳入的 9 项研究[15] [16] [26] [32]均报道了腹部手术患者术后肺不张的发生率。荟萃分析汇集的结果显示，与高 FiO_2 (60%~100%)组相比，围手术期低 FiO_2 (30%~40%)组患者腹部手术后肺不张的发生率显著降低[RR: 1.40; 95%CI: 1.08~1.81; $P = 0.01$]，具有中度异质性($I^2 = 64\%$, $P = 0.004$) (图 3)。

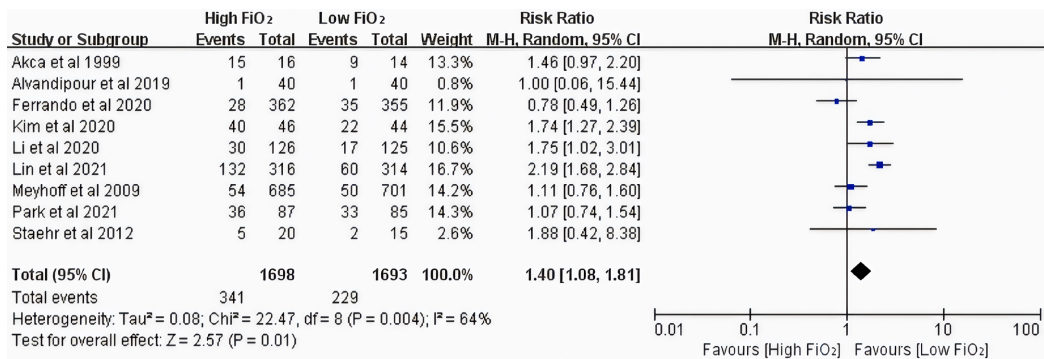


Figure 3. Forest plot of the association between postoperative atelectasis and perioperative fraction of inspired oxygen
图 3. 术后肺不张与围手术期吸入氧浓度之间关系的森林图

3.4. 亚组分析

5 项研究报道了呼气末正压的应用。在两项研究中, 高 FiO_2 和低 FiO_2 组术中应用呼气末正压并不会减少手术后肺不张[(RR: 1.29; 95%CI: 0.91~1.85; $P = 0.15$), 中度异质性($I^2 = 62\%$, $P = 0.03$)]. 而围手术期不使用呼气末正压时, 低 FiO_2 可以减少腹部手术后肺不张的发生[(RR: 1.54; 95%CI: 1.03~2.30; $P = 0.01$), 具有中度异质性($I^2 = 68\%$, $P = 0.02$)] (图 4)。

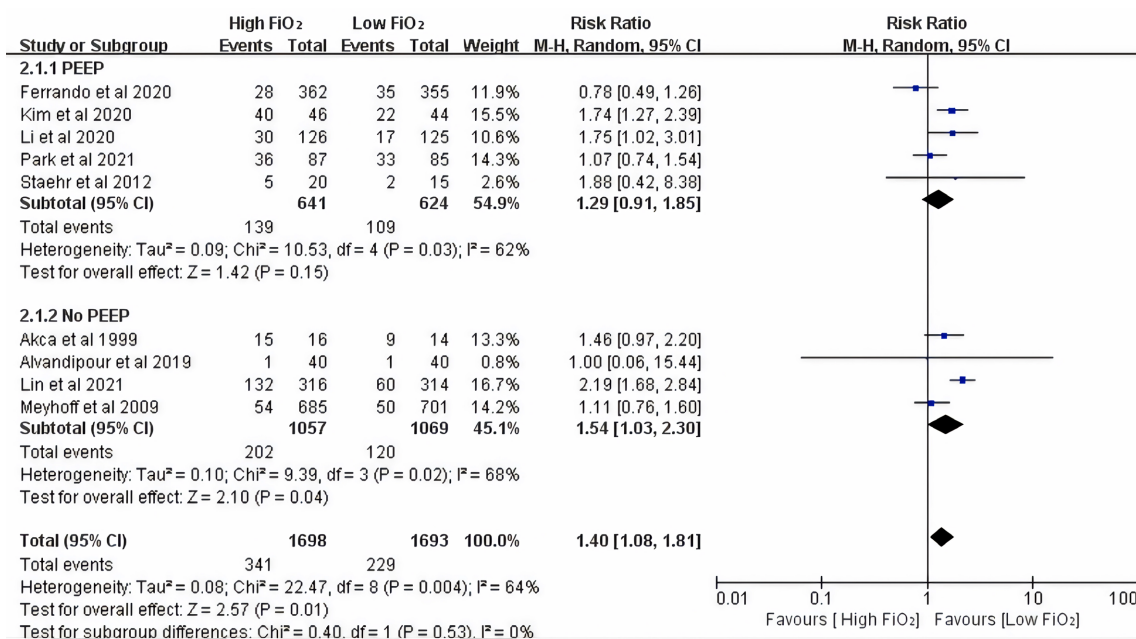


Figure 4. Forest plot for subgroup analysis stratified by application of positive end-expiratory pressure (PEEP)

图 4. 按照是否应用呼气末正压进行亚组分析的森林图

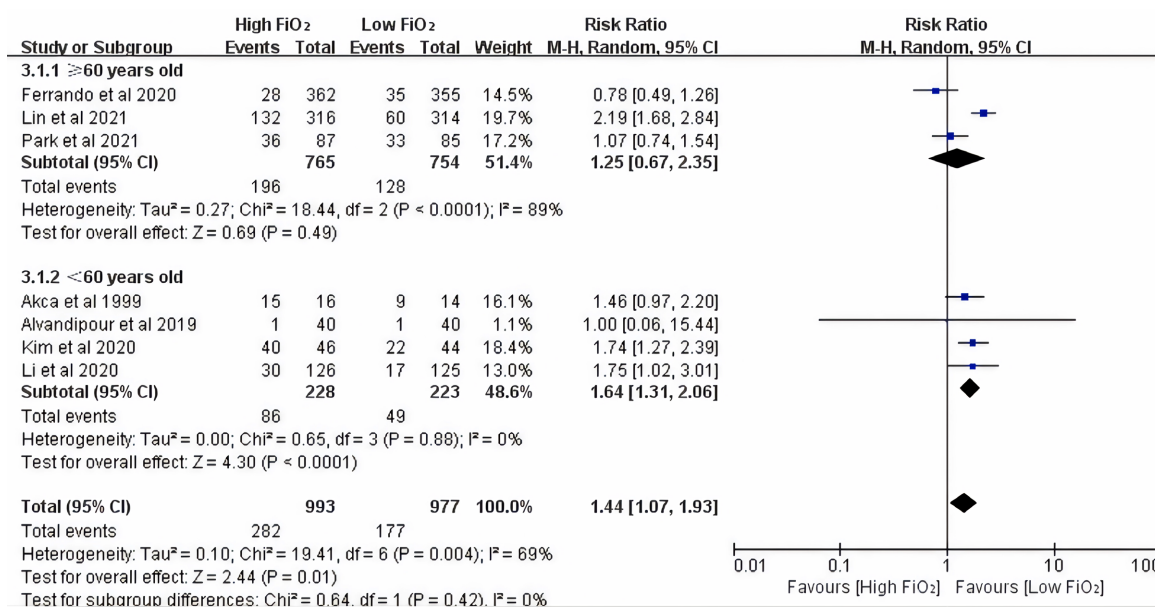


Figure 5. Forest plot for subgroup analysis stratified by age

图 5. 按年龄划分进行亚组分析的森林图

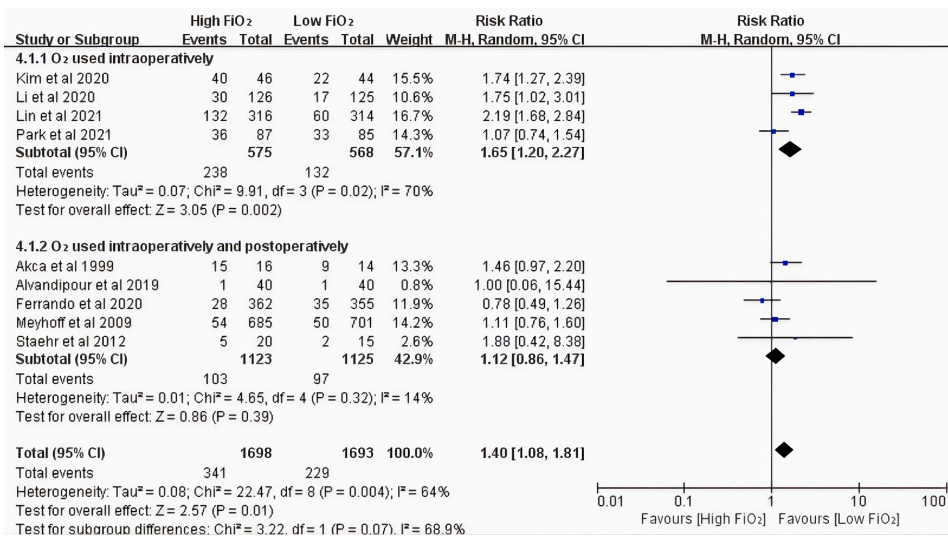


Figure 6. Forest plot for subgroup analysis stratified by oxygen delivery strategy
图 6. 按照给氧策略进行亚组分析的森林图

三项研究涉及患者平均年龄 ≥ 60 岁[16] [28] [30], 另有四项研究涉及患者平均年龄 < 60 岁[15] [27] [29] [31], 其余两项研究涉及患者平均年龄从 58 岁到 64 岁不等[26] [32]。在平均年龄 < 60 岁的亚组中, 低 FiO₂ 显著降低了术后肺不张的发生率[(RR: 1.64; 95%CI: 1.31~2.06; $P < 0.0001$), 无异质性($I^2 = 0\%$, $P = 0.88$)], 而在平均年龄 ≥ 60 岁的亚组中两组之间没有发现显著差异[(RR: 1.25; 95%CI: 0.67~2.35; $P = 0.49$), 具有高异质性($I^2 = 89\%$, $P < 0.0001$)] (图 5)。

在五项研究中[26] [27] [30]-[32], 患者于术中和术后都进行了吸氧, 其余四项研究患者仅在术中进行了吸氧[15] [16] [28] [29]。如图 6 所示, 仅在术中吸氧的患者, 低 FiO₂ 可以减少术后肺不张的发生率[(RR: 1.65; 95%CI: 1.20~2.27; $P = 0.002$), 具有中度异质性($I^2 = 70\%$, $P = 0.02$)]。对于术中和术后都吸氧的患者来说, 高 FiO₂ 和低 FiO₂ 均不会改变术后肺不张的发生率[(RR: 1.12; 95%CI: 0.86~1.47; $P = 0.39$), 异质性较低($I^2 = 14\%$, $P = 0.32$)] (图 6)。

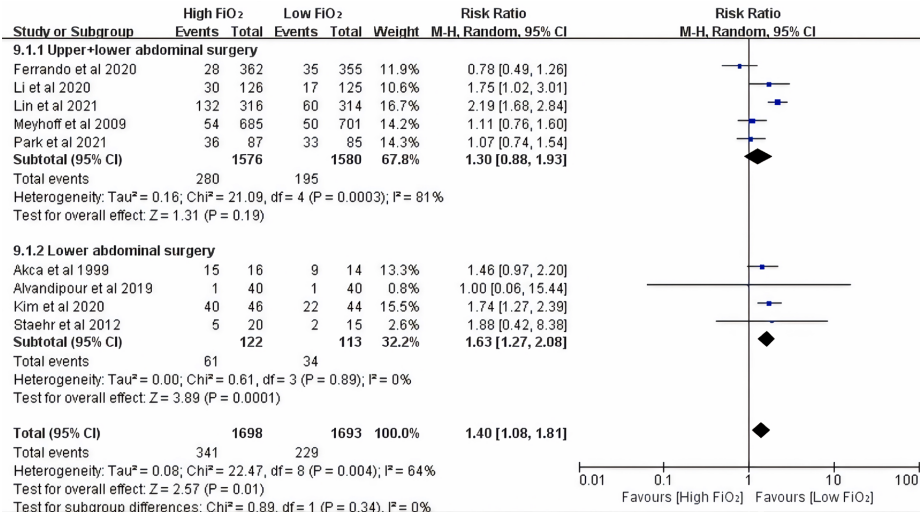


Figure 7. Forest plot for subgroup analysis stratified by surgical incision site
图 7. 按照手术切口部位进行亚组分析的森林图

四项研究[27] [29] [31] [32]报道了接受下腹部手术的患者围手术期低 FiO_2 可以预防术后肺不张[(RR: 1.63; 95%CI: 1.27~2.08; $P = 0.0001$), 无异质性($I^2 = 0\%$, $P = 0.89$)]. 五项研究涉及了接受上腹部手术和下腹部手术的患者[15] [16] [26] [28] [29], 高 FiO_2 患者的术后肺不张发生率与低 FiO_2 组无差异[(RR: 1.30; 95%CI: 0.88~1.93; $P = 0.19$), 异质性较低($I^2 = 81\%$, $P = 0.0003$)] (图 7)。

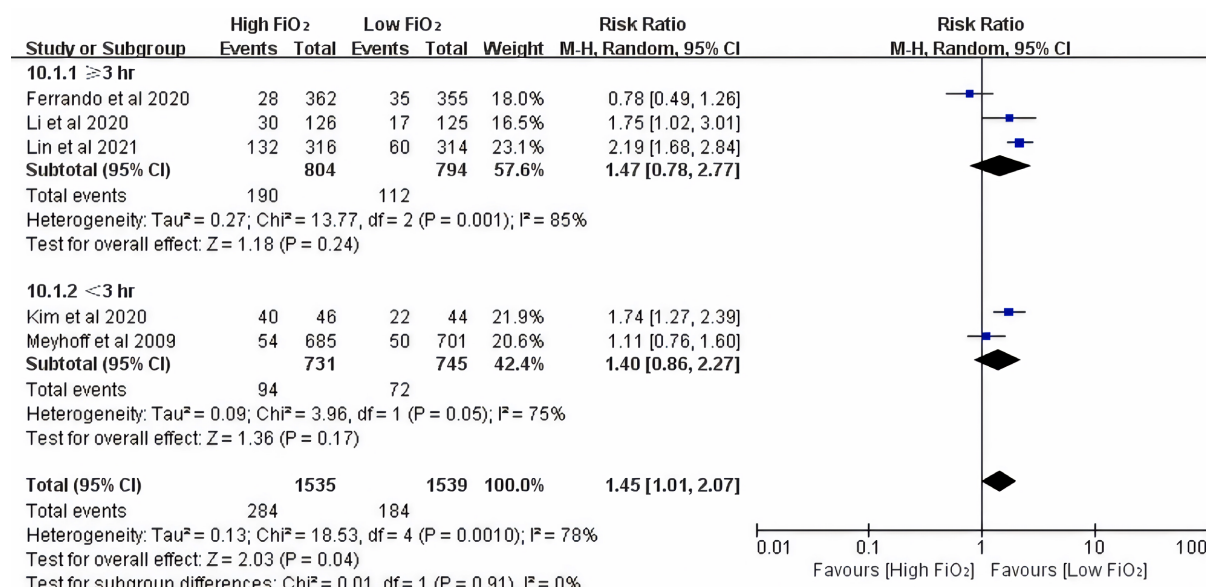


Figure 8. Forest plot for subgroup analysis stratified by surgical time

图 8. 按手术时间进行亚组分析的森林图

三项研究纳入的患者平均手术时长 ≥ 3 小时[15] [28] [30], 而在两项研究中[26] [29]平均手术时间相对较短(小于 3 小时)。高 FiO_2 和低 FiO_2 组术后肺不张发生率无差异[(RR: 1.47; 95%CI: 0.78~2.77; $P = 0.24$), 具有较高的异质性($I^2 = 85\%$, $P = 0.001$)], [(RR: 1.40; 95%CI: 0.86~2.27; $P = 0.17$), 具有较高的异质性($I^2 = 75\%$, $P = 0.05$)] (图 8)。

3.5. 术后肺不张的严重程度

四项研究报道了术后肺不张的严重程度[16] [27] [29] [32]。然而, 不一致的数据格式和小样本量使我们无法从结果中识别出任何明确的趋势, 也无法检测出高 FiO_2 组和低 FiO_2 组术后肺不张严重程度的差异。

3.6. 敏感性分析

排除 Lin 的研究和 Meyhoff 的研究, 异质性显著降低, 究其原因, 两项研究均涉及急诊手术患者, 而急诊手术是术后肺部并发症的重要危险因素[33] [34] ($I^2 = 45\%$, $P = 0.09$) (图 S2)。

4. 讨论

我们对 9 项随机对照试验的荟萃分析结果显示, 围手术期低 FiO_2 (30%~40%)显著降低了接受腹部手术的患者术后肺不张的发生率, 特别是 60 岁以下和接受下腹部手术的患者。无论是高 FiO_2 (60%~100%) 组还是低 FiO_2 组 (30%~40%), 使用呼气末正压对预防腹部手术后肺不张无益。

既往, 三项荟萃分析报道了围手术期不同 FiO_2 对术后肺功能的影响[17] [18] [35]。然而, 他们关注的

是接受不同类型手术的患者,因此缺乏研究结果的特异性。另外,既往荟萃分析的结论是基于高异质性和较低质量的证据,这使得其结论不足以说明围手术期 FiO_2 对肺不张的影响。

据我们所知,这是首次关注围手术期 FiO_2 影响腹部手术后肺不张的系统回顾和荟萃分析。此外,根据腹部手术后肺部并发症的危险因素进行综合亚组分析和敏感性分析,有助于评估我们的研究结果的可靠性。

我们的研究提示围手术期低 FiO_2 (30%~40%)有利于减少腹部手术后的肺不张。在临床工作中,麻醉医生通过提高患者 FiO_2 来应对围术期低氧血症事件的发生,这可能导致患者血氧浓度过高。此外,世界卫生组织在 2016 年发布的一项指南建议使用高 FiO_2 (80%)改善患者预后[36]。作为麻醉医生,我们应该权衡围手术期不同 FiO_2 水平的优缺点。

年龄的增加与术后肺部并发症的高发生率密切相关[7] [8]。本研究提示,对于平均年龄 ≥ 60 岁行腹部手术的患者,围手术期低 FiO_2 (30%~40%)对于预防术后肺不张无益。我们知道,年龄可以反映身体机能状况,术后肺不张是由于靶器官功能障碍和患者不良的身体状况导致的[7] [37]。因此,进一步的研究应集中于 60 岁以上患者术后肺不张的预防。

肺保护性通气策略中呼气末正压的有益作用,已被临床医生广泛接受[38]-[40]。然而,手术过程中呼气末正压的理想水平尚不清楚。在我们的研究中,我们发现在手术中同时应用呼气末正压,低 FiO_2 预防术后肺不张的有益作用将消失。因此,进一步研究需要关注可以预防术后肺不张的呼气末正压理想水平以及围手术期 FiO_2 的理想水平。

临床工作中,考虑到患者通气不足及随后的低氧血症,给予患者高浓度氧似乎令人信服。我们的研究表明,只有术中低 FiO_2 有利于预防腹部手术后的肺不张。然而,目前关于 FiO_2 对术后肺不张影响的证据充满了混杂因素,如是否使用肺保护性通气、缺乏可行的对照组[41]-[43]。因此,在未来的研究中,应独立评估氧合对术后肺不张的影响。

与上腹部切口相比,下腹部手术切口的患者术后肺不张的发生率降低[8]。在我们的研究中,下腹切口的患者受益于围手术期低 FiO_2 (30%~40%)来减少术后肺不张的发生率。我们知道,上腹部切口比下腹部切口更接近横膈,因此,上腹部切口手术更容易推动横膈向头端移动,对肺功能影响更显著,导致术后肺不张的发生率较高[5]-[8]。

为了评估个体研究对整体效应的影响,并探讨异质性的来源,我们通过排除特定研究进行了敏感性分析。排除一项涉及急诊手术患者的研究后,异质性下降到一个相对较低的水平($I^2 = 41\%$) [28]。值得注意的是,急诊手术是术后肺部并发症的一个重要危险因素[33] [34]。

5. 局限性

我们的研究存在一些局限性。首先,随着手术时间的延长,术后肺部并发症的发生率逐渐增加。当手术持续超过 3 小时时,术后肺不张发生率增加[7] [8]。然而,在我们的研究中,按手术时间进行的亚组分析样本量小,异质性高。因此,进一步的研究应关注手术时间与围手术期低 FiO_2 (30%~40%)用于预防腹部手术后肺不张的有益影响之间的关系。其次,不同纳入研究对术后肺不张的定义不同,同时不同研究的数据是在术后不同时间点获取的,这可能是中度异质性的另一个因素。

总之,我们的荟萃分析提供了中等质量的证据,证明了术中低 FiO_2 (30%~40%)降低下腹手术患者术后肺不张的风险,同时减少了平均年龄 < 60 岁的患者术后肺不张的发生。

声 明

我们声明在本研究中不存在利益冲突。

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附 录

Table S1. Search strategy

表 S1. 检索策略

PubMed	(((((Fractional concentration of inspired oxygen[Title/Abstract]) OR (Fraction of Inspired Oxygen[Title/Abstract])) OR (Inspiratory oxygen Fraction[Title/Abstract])) OR (Inspired Oxygen Fraction[Title/Abstract])) OR (FiO2[Title/Abstract])) OR (FIO2[Title/Abstract])) AND (((((((((((((((((((Pulmonary Atelectasis[Title/Abstract]) OR (Atelectases, Pulmonary[Title/Abstract])) OR (Atelectasis, Pulmonary[Title/Abstract])) OR (Pulmonary Atelectases[Title/Abstract])) OR (Lung Collapse Atelectasis Atelectases Congestive Pulmonary Atelectasis Atelectases, Congestive Pulmonary Atelectasis, Congestive Pulmonary Congestive Pulmonary Atelectases Pulmonary Atelectases, Congestive Pulmonary Atelectasis, Congestive Congestive Atelectasis Atelectases, Congestive Congestive Atelectases Atelectasis, Congestive Resorption Pulmonary Atelectasis Atelectases, Resorption Pulmonary Atelectasis, Resorption Pulmonary Pulmonary Atelectasis, Resorption Pulmonary Atelectasis, Resorption Resorption Pulmonary Atelectases Resorption Atelectasis Atelectases, Resorption Atelectasis, Resorption Resorption Atelectases Pulmonary complication Pulmonary Complications Cmplications, Pulmonary Complication, Pulmonary[Title/Abstract])) OR (Atelectasis[Title/Abstract])) OR (Atelectases[Title/Abstract])) OR (Congestive Pulmonary Atelectasis[Title/Abstract])) OR (Atelectases, Congestive Pulmonary[Title/Abstract])) OR (Atelectasis, Congestive Pulmonary[Title/Abstract])) OR (Congestive Pulmonary Atelectases[Title/Abstract])) OR (Pulmonary Atelectases, Congestive[Title/Abstract])) OR (Pulmonary Atelectasis, Congestive[Title/Abstract])) OR (Congestive Atelectases[Title/Abstract])) OR (Atelectases, Congestive[Title/Abstract])) OR (Congestive Atelectases[Title/Abstract])) OR (Atelectasis, Congestive[Title/Abstract])) OR (Resorption Pulmonary Atelectasis[Title/Abstract])) OR (Atelectases, Resorption Pulmonary[Title/Abstract])) OR (Atelectasis, Resorption Pulmonary[Title/Abstract])) OR (Pulmonary Atelectases, Resorption[Title/Abstract])) OR (Pulmonary Atelectasis, Resorption[Title/Abstract])) OR (Resorption Pulmonary Atelectases[Title/Abstract])) OR (Resorption Atelectasis[Title/Abstract])) OR (Atelectases, Resorption[Title/Abstract])) OR (Atelectasis, Resorption[Title/Abstract])) OR (Resorption Atelectases[Title/Abstract])) OR (Pulmonary complication[Title/Abstract])) OR (Pulmonary Complications[Title/Abstract])) OR (Complications, Pulmonary[Title/Abstract])) OR (Complication, Pulmonary[Title/Abstract]))
Web of Science	#1 TS=((Pulmonary Atelectasis) OR (Atelectases, Pulmonary) OR (Atelectases, Pulmonary) OR (Atelectasis, Pulmonary) OR (Pulmonary Atelectases) OR (Lung Collapse) OR (Atelectasis) OR (Atelectases) OR (Congestive Pulmonary Atelectasis) OR (Atelectases, Congestive Pulmonary) OR (Atelectasis, Congestive Pulmonary) OR (Congestive Pulmonary Atelectases) OR (Pulmonary Atelectases, Congestive) OR (Pulmonary Atelectasis, Congestive) OR (Congestive Atelectasis) OR (Atelectases, Congestive) OR (Congestive Atelectases) OR (Atelectasis, Congestive) OR (Resorption Pulmonary Atelectasis) OR (Complication, Pulmonary) OR (Complications, Pulmonary) OR (Pulmonary complication) OR (Atelectases, Resorption Pulmonary) OR (Atelectases, Resorption Pulmonary) OR (Atelectasis, Resorption Pulmonary)) #2 TS = ((Fractional concentration of inspired oxygen) OR (Fraction of Inspired Oxygen) OR (Inspiratory oxygen Fraction) OR (Inspired Oxygen Fraction) OR (FiO2) OR (FIO2)) #3 #1 AND #2
Embase	#1 'pulmonary atelectasis': ab,ti OR 'atelectases, pulmonary': ab,ti OR 'atelectasis, pulmonary': ab,ti OR 'pulmonary atelectases': ab,ti OR 'lung collapse': ab,ti OR atelectasis: ab,ti OR atelectases: ab,ti OR 'congestive pulmonary atelectasis': ab,ti OR 'atelectases, congestive pulmonary': ab,ti OR 'atelectasis, congestive pulmonary': ab,ti OR 'congestive pulmonary atelectases': ab,ti OR 'pulmonary atelectases, congestive': ab,ti OR 'pulmonary atelectasis, congestive': ab,ti OR 'congestive atelectasis': ab,ti OR 'atelectases, congestive congestive atelectases atelectasis, congestive resorption pulmonary atelectasis atelectases, resorption pulmonary atelectasis, resorption pulmonary pulmonary atelectases, resorption pulmonary atelectasis, resorption resorption pulmonary atelectases resorption atelectasis atelectases, resorption atelectasis, resorption resorption atelectases pulmonary complication pulmonary complications cmplications, pulmonary complication, pulmonary': ab,ti OR 'congestive atelectases': ab,ti OR 'atelectasis, congestive': ab,ti OR 'resorption pulmonary atelectasis': ab,ti OR 'atelectases, resorption pulmonary': ab,ti OR 'atelectasis, resorption pulmonary': ab,ti OR 'pulmonary atelectases, resorption': ab,ti OR 'pulmonary atelectasis, resorption': ab,ti OR 'resorption atelectasis': ab,ti OR 'atelectases, resorption': ab,ti OR 'atelectasis, resorption': ab,ti OR 'resorption atelectases': ab,ti OR 'pulmonary complication': ab,ti OR 'pulmonary complications': ab,ti OR 'cmplications, pulmonary': ab,ti OR 'complication, pulmonary': ab,ti #2 'fractional concentration of inspired oxygen':ab,ti OR 'fraction of inspired oxygen': ab,ti OR 'inspiratory oxygen fraction': ab,ti OR 'inspired oxygen fraction': ab,ti OR fio2:ab,ti #3 #1 AND #2

续表

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#1 (Pulmonary Atelectasis): ti, ab, kw OR (Atelectases, Pulmonary): ti, ab, kw OR (Atelectasis, Pulmonary): ti, ab, kw OR (Pulmonary Atelectases): ti, ab, kw OR (Lung Collapse): ti, ab, kw
 #2(Atelectasis): ti, ab, kw OR (Atelectases): ti, ab, kw OR (Congestive Pulmonary Atelectasis): ti, ab, kw OR (Atelectases, Congestive Pulmonary): ti, ab, kw (Atelectasis, Congestive Pulmonary): ti, ab, kw, kw
 #3(Congestive Pulmonary Atelectases): ti, ab, kw OR (Pulmonary Atelectases, Congestive): ti, ab, kw OR (Pulmonary Atelectasis, Congestive): ti, ab, kw OR (Congestive Atelectasis): ti, ab, kw OR (Atelectases, Congestive): ti,ab,kw
 #4(Congestive Atelectases): ti, ab, kw OR (Atelectasis, Congestive): ti, ab, kw OR (Resorption Pulmonary Atelectasis): ti, ab, kw OR (Atelectases, Resorption Pulmonary): ti, ab, kw OR (Atelectasis, Resorption Pulmonary): ti, ab, kw
 #5(Pulmonary Atelectases, Resorption): ti, ab, kw OR (Pulmonary Atelectasis, Resorption): ti, ab, kw OR (Resorption Pulmonary Atelectases): ti,ab,kw OR (Resorption Atelectasis): ti, ab, kw OR (Atelectases, Resorption): ti, ab, kw
 #6(Atelectasis, Resorption): ti, ab, kw OR (Resorption Atelectases): ti, ab, kw OR (Pulmonary complication): ti, ab, kw OR (Pulmonary Complications Cmplications, Pulmonary Complication, Pulmonary): ti, ab, kw OR (Cmplications, Pulmonary): ti, ab, kw
 #7(Fractional concentration of inspired oxygen): ti, ab, kw OR (Fraction of Inspired Oxygen): ti, ab, kw OR (Inspiratory oxygen Fraction): ti, ab, kw OR (Inspired Oxygen Fraction): ti, ab, kw OR (FIO2): ti, ab, kw
 #8 #1 OR #2 OR #3 OR #4 OR #5 OR #6
 #9 #7 AND #8

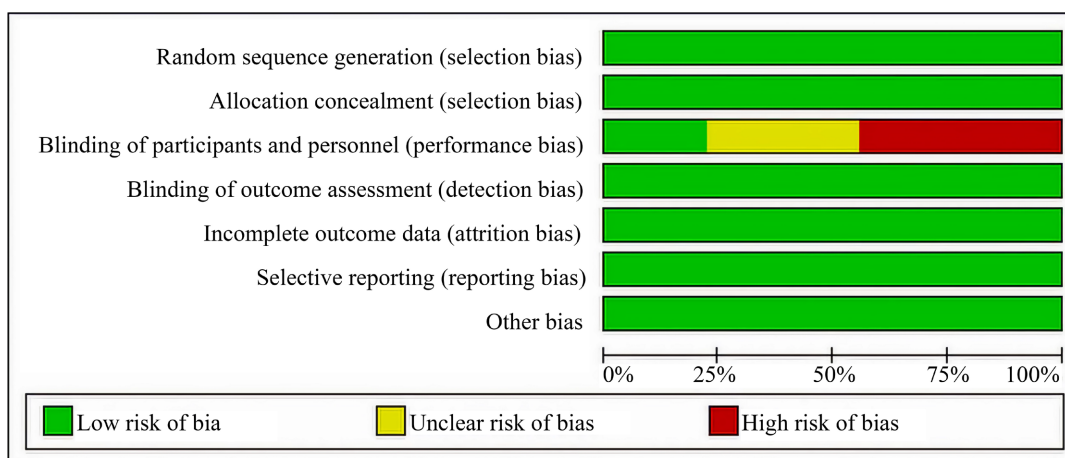


Figure S1. Summary of risk of bias assessment

图 S1. 风险偏移评估总结

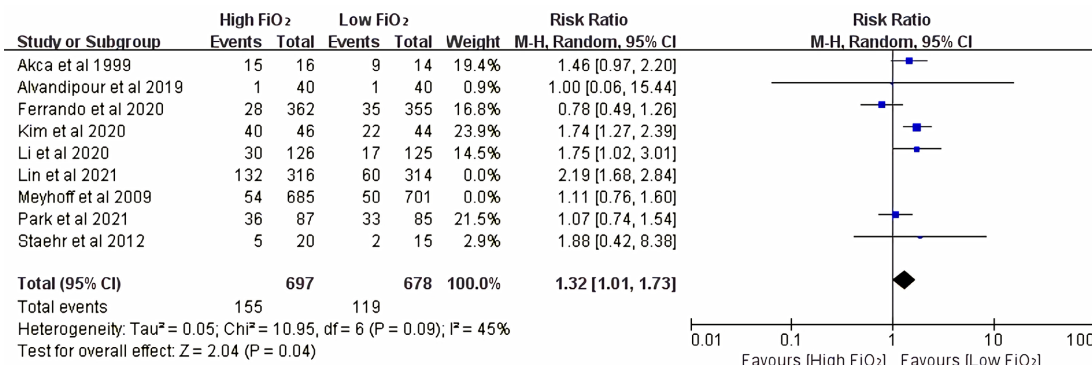


Figure S2. Sensitivity analysis was performed by excluding studies involving emergency surgery

图 S2. 通过排除包括急诊手术在内的研究进行敏感性分析