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# Risk factors of intraabdominal hypertension in cardiac surgery: A systematic review and meta-analysis

*Kardiyak cerrahide intraabdominal hipertansiyonun risk faktörleri: Sistematik derleme ve meta-analiz*

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***ABSTRACT***

***Background:*** In this review, we discuss the risk factors of intraabdominal hypertension developing after cardiac surgery.

***Methods:*** We used records from electronic databases (PubMed, Scopus, Web of Science and Ovid) between 1980 and 2025. All studies in which possible pre- and intraoperative risk factors (age, sex, hypertension, diabetes mellitus, lung disease, coronary artery bypass grafting, body mass index and, cardiopulmonary bypass duration) were recorded were included in the analysis. The results of the studies were evaluated with a random or fixed effect model depending on the presence of heterogeneity ($I^2$ >25%).

***Results:*** A total of 4,286 articles were found from the database search. After analyzing the abstract and full texts, six articles which met the inclusion criteria and covered 696 patients were included in the analysis. The overall rate of intraabdominal hypertension was 44.68%. Age (standardized mean difference [SMD]: 0.303, 95% confidence interval [CI]: 0.123-0.484, p<0.001), hypertension (odds ratio [OR]=0.524, 95% CI: 0.087-0.960, p=0.019), body mass index (SMD: 0.532, 95% CI: 0.004-1.061, p=0.048), and cardiopulmonary bypass duration (SMD: 0.545, 95% CI: 0.184-0.907, p=0.003) were preoperative risk factors.

***Conclusion:*** The patient's age, hypertension, body mass index, and duration of cardiopulmonary bypass are the risk factors for the development of intraabdominal hypertension after cardiac surgery. However, larger studies are needed to avoid heterogeneity of results.

***Keywords:*** Cardiac surgical procedures, intraabdominal hypertension, risk factors, meta-analysis.

***ÖZ***

***Amaç:*** Bu derlemede, kalp cerrahisi sonrası gelişen intraabdominal hipertansiyonun risk faktörleri irdelendi.

***Çalışma planı:*** 1980-2025 yılları arasındaki elektronik veri tabanlarının (PubMed, Scopus, Web of Science ve Ovid) kayıtları kullanıldı. Muhtemel ameliyat öncesi ve ameliyat sırası risk faktörlerinin (yaş, cinsiyet, hipertansiyon, diabetes mellitus, akciğer hastalığı, koroner arter baypas greftleme, vücut kitle indeksi ve kardiyopulmoner baypas süresi) kaydedildiği tüm çalışmalar analize dahil edildi. Çalışmaların sonuçları, heterojenliğin varlığına ($I^2$ >%25) bağlı olarak rastgele veya sabit etki modeli ile değerlendirildi.

***Bulgular:*** Veri tabanı aramasında toplam 4286 makale bulundu. Özet ve tam metinler analiz edildikten sonra, dahil edilme kriterlerini karşılayan ve 696 hastayı kapsayan altı makale analize dahil edildi. Genel intraabdominal hipertansiyon oranı %44.68 idi. Yaş (standardize ortalama fark [SMD]: 0.303, %95 güven aralığı [GA]: 0.123-0.484, p<0.001), hipertansiyon (olasılık oranı [OR]=0.524, %95 GA: 0.087-0.960, p=0.019), vücut kitle indeksi (SMD: 0.532, %95 GA: 0.004-1.061, p=0.048), ve kardiyopulmoner bypass süresi (SMD: 0.545, %95 GA: 0.184-0.907, p=0.003) ameliyat öncesi risk faktörleri idi.

***Sonuç:*** Hastanın yaşı, hipertansiyonu, vücut kitle indeksi ve kardiyopulmoner baypas süresi kardiyak cerrahi sonrası intraabdominal hipertansiyon gelişimi için risk faktörleridir. Ancak, sonuçların heterojenliğinden kaçınmak için daha büyük çalışmalara ihtiyaç vardır.

***Anahtar sözcükler:*** Kardiyak cerrahi prosedürleri, intraabdominal hipertansiyon, risk etkenleri, meta-analiz.

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Intraabdominal pressure (IAP) is defined as steady-state pressure of the abdominal cavity according to the guidelines of the World Society of the Abdominal Compartment Syndrome.[1] Intraabdominal hypertension (IAH) is defined as elevated IAP above 12 mmHg and higher.[1]

This clinical condition can affect many organ systems. Increased IAP can produce impairment in renal function as a local phenomenon caused by direct renal compression.[2] Also, elevated IAP increases the central venous pressure (CVP) and intracranial pressures and, then, initiates systemic hypertension (HT).[3] Cardiovascular and pulmonary functions may be affected by increased IAP.[4,5]

The incidence of IAH after cardiac surgery has been reported as high as 83.3% in the literature.[6] This frequent situation leads to adverse consequences.[7] Although it is common and has important systemic effects, it is a rarely reported condition. In this review, we discuss pre- and intraoperative factors which increase the risk of developing IAH in cardiac surgery.

## MATERIALS AND METHODS

We applied database searching according to the guideline (Preferred reporting items for systematic review and meta-analysis protocols [PRISMA-P]).[8] We registered in the Prospective International Register of Systematic Reviews (PROSPERO) with identification number CRD420251044692. Only electronic databases were used, and also references of the related articles were reviewed. The articles that researched the risk factors including age, sex, HT, diabetes mellitus (DM), lung disease, coronary artery bypass grafting (CABG), body mass index (BMI), and, cardiopulmonary bypass (CPB) of IAH (IAP increases to ≥12 mmHg) after cardiac surgery were reviewed by four authors until February 3rd, 2025.

### Literature source and research strategy

We used records from electronic databases between 1980 and 2025. Language was limited to English. Four electronic databases were PubMed, Scopus, Web of Science, and Ovid. The keywords or combinations of them (heart surgery OR cardiac surgery OR valve surgery OR coronary artery bypass grafting, intraabdominal hypertension) were used. The clinical trials, multi-center, comparative, observational studies, randomized-controlled trials, controlled clinical trials, and evaluation studies were included.

### Inclusion and exclusion criteria

The retrospective or prospective clinical studies, regardless of sample size, were included. The main inclusion criteria were as follows: *(i)* clinical study, *(ii)* heart surgery (on- or off-pump) article in English. Exclusion criteria were as follows: *(i)* experimental studies, *(ii)* case reports, *(iii)* case series, *(iv)* review articles, and *(v)* peripheral vascular surgeries. Data of articles reported with figures, but not numerical values were excluded.

Four reviewers independently extracted data from studies. The fifth reviewer resolved the disagreement. We extracted publication information (first author's name, publication year, country, surgery, sample size, rate of IAH, and analysis result of trial). The number of patients with IAH and control group were recorded as data.

### Risk of bias and quality assessment

The Begg test was performed to assess the publication bias. Quality assessment of each trial was performed using Newcastle Ottowa scale. In terms of quality assessment, studies were considered as low (≥7 points), moderate (4-6 points) or high (<4 points) risk.

### Statistical analysis

Statistical analysis was performed using the Jamovi® version 2.5.6 software (The Jamovi project, Sydney, Australia). The standardized mean difference (SMD) or odds ratio (OR) and 95% confidence interval (CI) were used. The $I^2$ statistic was used for heterogeneity analysis. In case of heterogeneity, subgroup analysis and confirmation test (Bonferroni test) were performed. For analysis of the results fixed effects model or random effects model were used. If there was heterogeneity ($I^2$ >25%) results of the the analysis were evaluated with random effect model, if not it ($I^2$ <25%) was evaluated with fixed effect model. In random effect model analysis, the restricted maximum likelihood approach was used. A $p$ value of <0.05 was considered statistically significant. The publication bias ($tau^2$<0.05) was also visually confirmed with the funnel plots.

## RESULTS

A total of 4,286 articles were obtained and after excluding repeated (4,038) articles, 248 articles remained. The abstracts and titles of articles were reviewed and 198 articles irrelevant to the topic were excluded. A total of 40 of 50 articles were eliminated during examining full texts (case reports: 9, experimental: 1, review article: 11, editorial comments: 5, non-surgical interventions: 9, peripheral vascular surgery: 5). Four articles were excluded from quantitative analysis due to improper data format (the number of cases reflecting the risk factors in the groups or the numerical values such as the intergroup mean, standard deviation of the risk factors were not reported). A total of six trials with 696 patients were analyzed.

The rate of IAH was found as 44.68% (311/696).[6,9-13] In Figure 1, the database screening flowchart is presented. The articles are presented in Table 1.

First, we distinguished factors which were examined as risk factors in at least two studies among all studies. Then, the sample sizes, means, and standard deviations of each article were analyzed for the variables age, BMI, and CPB duration. Also, after recording sample sizes and rates of the factors, we analyzed the data for female sex, DM, HT, lung disease, and CABG.

There was heterogeneity for lung disease ($I^2$=26.64), BMI ($I^2$=81.42), and CPB duration ($I^2$=52.81) (Table 2). Therefore, we applied the random effects model for these risk factors (BMI, CPB duration, and lung diseases) and the fixed effects model for the other factors.

According to the analysis results, we found that age (SMD: 0.303, 95% CI: 0.123-0.484 and p<0.001), HT (OR: 0.524, 95% CI: 0.087-0.960 and p=0.019), BMI (SMD: 0.532, 95% CI: 0.004-1.061 and p=0.048), and CPB duration (SMD: 0.545, 95% CI: 0.184-0.907 and p=0.003) pose a risk for development of IAH. Heterogeneity was not observed in only two (HT and age) of these factors. The highest heterogeneity was observed in trials for BMI ($I^2$=81.42%). The results are presented in Table 2. Forest plots are presented in Figure 2-5.

The factors that affect the heterogeneity were not investigated for CVP and aortic cross clamp time (ACCT) variables due to insufficient numbers of studies included in the analysis (<3 studies). The main reason was the heterogeneous population

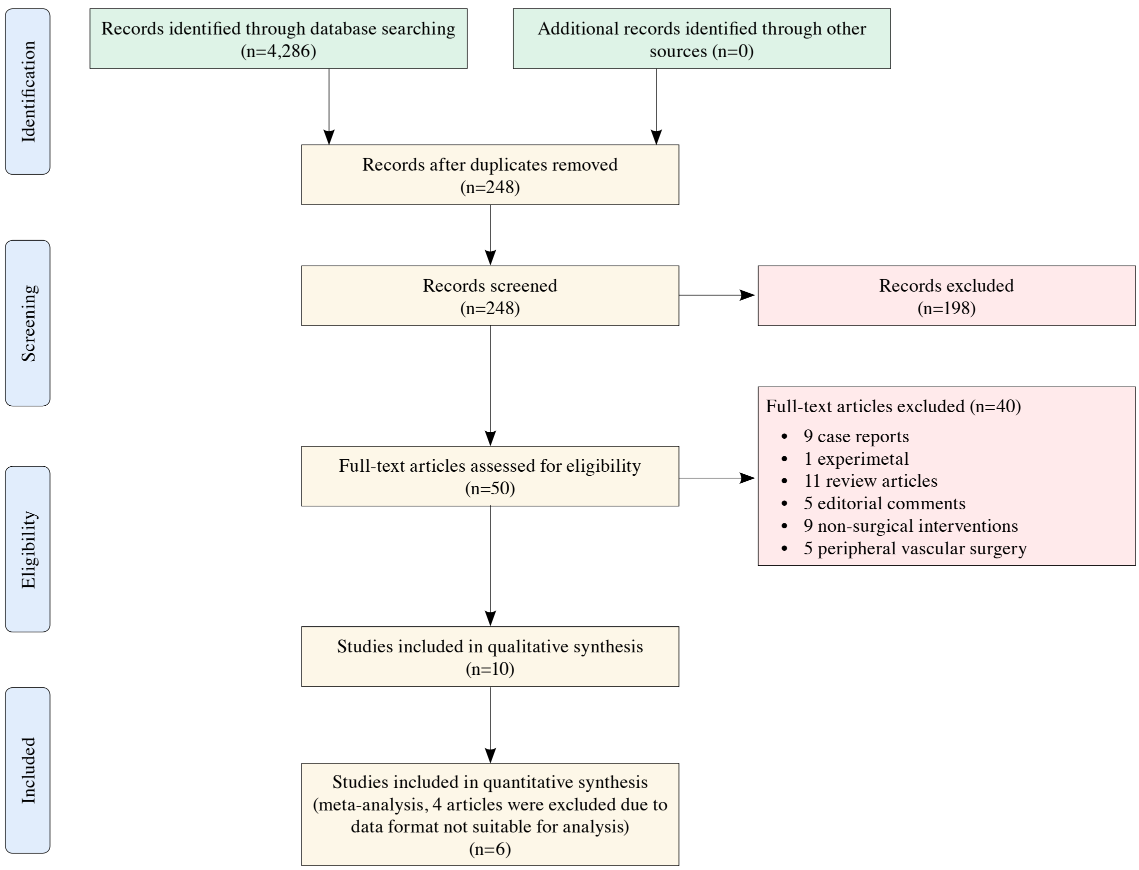


**Figure 1.** Study flowchart.

**Table 1. The studies included the analysis**

| Studies | Year | Country | Patients (n) | Male / Female (n) | IAH rate (%) | Definition of IAH | Type of surgery | Risk factors |
|---|---|---|---|---|---|---|---|---|
| Richer-Séguin et al.[12] | 2022 | Canada | 191 | 154/37 | 32 | + | CABG and other procedures | BMI, CVP, mean pulmonary artery pressure |
| Kılıç et al.[10] | 2020 | Türkiye | 100 | 74/26 | 49 | + | CABG+valve | IAP baseline, age, HT, duration of CPB, intraoperative lactate levels, use of red blood cells |
| Smit et al.[13] | 2016 | Netherland | 186 | 138/48 | 30 | + | CABG and other procedures | BMI |
| Mazzeffi et al.[6] | 2016 | USA | 42 | 29/13 | 83 | + | CABG and other procedures | Urine neutrophil gelatinase-associated lipocalin |
| Iyer and D'Amours[11] | 2014 | Australia | 108 | 82/26 | 46 | + | | Albumin, AST, APTT, CVP, CPB, Amount of cristalloid |
| Dalfino et al.[9] | 2013 | Italy | 69 | 43/26 | 31.8 | + | CABG+Valve | Baseline IAP, CVP, fluid balance |

CABG: Coronary artery bypass grafting; BMI: Body mass index; CVP: Central venous pressure; IAP: Intraabdominal pressure; HT: Hypertension; CPB: Cardio-pulmonary bypass; AST: Aspartate aminotransferase; APTT: Activated partial thromboplastin time.

of the studies according to the on- and off-pump techniques in BMI ($I^2$=53%) and CPB ($I^2$=70%) time according to the subgroup analysis. In our analysis, the presence of high heterogeneity, particularly in terms of BMI, and CPB duration variables, requires us to take into account correction tests (such as the Bonferroni correction test). In this case, the *p* value for BMI and CPB duration would be 0.0083. Although this p value did not change the result for CPB duration, it may have affected the significance value we obtained for BMI. However, in this case, we accepted the *p* value as 0.05 for all analyses in order not to cause truly significant differences to be overlooked (Type 2 error). The situation that emerged particularly for BMI can be definitively confirmed with new large-scale studies that will reduce heterogeneity.

The weights of the studies covering the variables we found to be risk factors for IAH were examined in terms of their effects on the results obtained. The study of Richer-Séguin et al.[12] had higher values for HT (48.07%) and age (39.57%). These values ranged from 18.24% to 29.17% for BMI and 14.08% to 29.65% for CPB duration.

There was no publication bias for lung disease, BMI, and CPB duration ($tau^2$>0.05). This situation was also visually confirmed with the funnel plots. The quality of the studies was assessed according to the Newcastle-Ottowa Scale (Table 3).

## DISCUSSION

In this review, we discuss pre- and intraoperative factors which increase the risk of developing IAH in cardiac surgery. As a result of our analysis, we concluded that age, HT, BMI, and CPB duration were preoperative risk factors for the development of postoperative IAH. Concomitant diseases such as lung disease and DM, isolated CABG and female sex were not significant factors.

Considering the overall patient population, many different causes lead to an increase in IAP. These include morbid obesity, neoplasm, ileus, and excessive fluid replacement, particularly with crystalloids.[14] However, hypothermia, hypotension, and acidosis also cause IAH.[15] Although abdominal surgery, in particular, is an important factor in surgery, the increase in IAP is also considerably high in cardiac surgery.[1,6]

Increased IAP has cerebral (increased jugular venous pressure, increased intracerebral pressure and decreased cerebral blood flow), cardiovascular (impaired venous return, peripheral edema and

**Table 2. The summary of the analysis**

| Studies | OR | CI | | *p* | Q | df | $I^2$ | *p* | $Tau^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Sex (female) | –0.103 | –0.475 | 0.269 | 0.588 | 5.921 | 5 | 15.55 | 0.314 | 0 |
| CABG | –0.235 | –0.653 | 0.183 | 0.271 | 2.369 | 3 | 0 | 0.500 | 0 |
| Lung disease | 0.146 | –1.005 | 1.297 | 0.804 | 2.726 | 2 | **26.64** | 0.256 | 0.277 |
| DM | 0.281 | –0.163 | 0.724 | 0.215 | 2.427 | 3 | 0 | 0.489 | 0 |
| HT | 0.524 | 0.087 | 0.960 | **0.019** | 2.556 | 3 | 0 | 0.465 | 0 |

| Study | SMD | CI | | *p* | Q | df | $I^2$ | *p* | $Tau^2$ |
|---|---|---|---|---|---|---|---|---|---|
| Age | 0.303 | 0.123 | 0.484 | **<0.001** | 4.274 | 4 | 6.41 | 0.370 | 0 |
| BMI | 0.532 | 0.004 | 1.061 | **0.048** | 1.615 | 3 | **81.42** | 0.001 | 0.225 |
| CPB duration | 0.545 | 0.184 | 0.907 | **0.003** | 6.280 | 3 | **52.81** | 0.099 | 0.069 |

OR: Odd ratio; CI: Confidence interval; CABG: Coronary artery bypass grafting; DM: Diabetes mellitus; HT: Hypertension; BMI: Body mass index; CPB: Cardiopulmonary bypass.

increased CVP), pulmonary (diaphragm pushing up, respiratory restriction, increased intrathoracic pressure, decreased functional residual capacity and hypoxia) and renal (decreased blood flow, oliguria, anuria) adverse effects.[16] In addition, IAH leads to increased morbidity and mortality.[15] When these results are taken into consideration, the importance of IAH in cardiac surgery becomes more apparent.

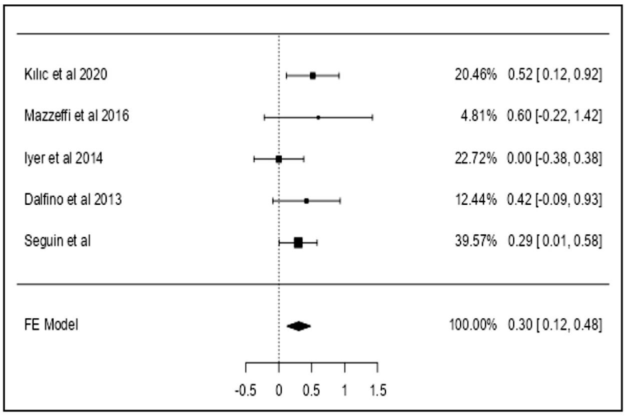


**Figure 2.** Forest plot for analysis of age.

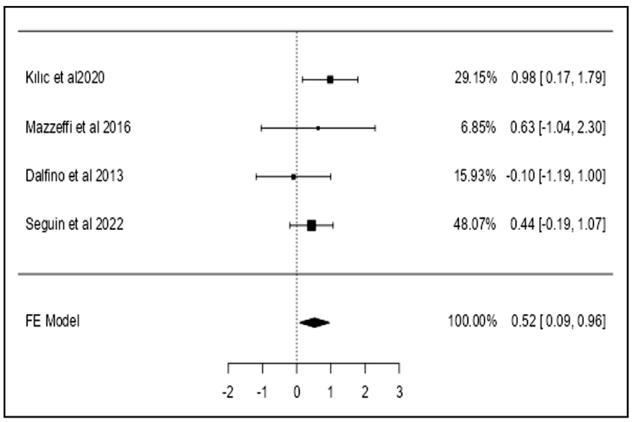


**Figure 3.** Forest plot for analysis of hypertension.

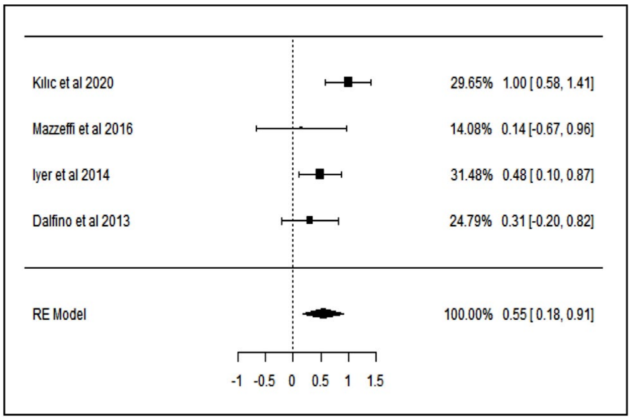


**Figure 4.** Forest plot for analysis of cardiopulmonary bypass duration.

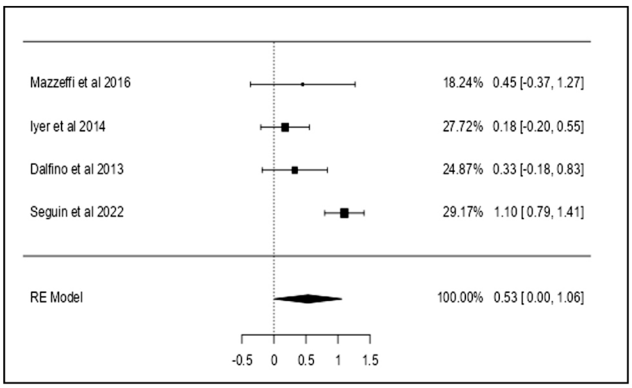


**Figure 5.** Forest plot for analysis of body mass index.

**Table 3. Newcastle-Ottawa Scale Assessment of Study Quality**

| | Selection | | | | Comparability | | Exposure/outcome | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Studies | 1 | 2 | 3 | 4 | 1 | 2 | 1 | 2 | 3 | Total |
| Richer-Séguin et al.[12] | * | * | * | * | * | 0 | * | * | * | 8/9 |
| Kılıç et al.[10] | * | * | * | * | * | 0 | 0 | * | * | 7/9 |
| Smit et al.[13] | * | * | * | * | * | * | 0 | * | * | 8/9 |
| Mazzeffi et al.[6] | * | * | * | * | * | * | 0 | * | 0 | 7/9 |
| Iyer and D'Amours[11] | * | * | * | * | * | 0 | 0 | * | * | 7/9 |
| Dalfino et al.[9] | * | * | * | * | * | 0 | 0 | * | * | 7/9 |

The frequency of IAH reaches its highest value particularly on the second and third days in the postoperative period.[11]

Zhang et al.[7] showed that right heart lesions, redo sternotomy, baseline CVP level, IAP values and deep hypothermic circulatory arrest were risk factors for IAH in children who underwent cardiac surgery. They found that mechanical ventilation, sepsis and IAH affected postoperative outcomes in this group of patients.

Studies covering the adult patient group were reanalyzed by Holodinsky et al.[17] in a meta-analysis. In this meta-analysis, they examined IAH risk factors. In this analysis, where they selected intensive care unit (ICU) patients as the patient group, 25 independent risk factors for IAH were analyzed. The patient population is not homogeneous due to the variety of ICUs in the included studies (trauma, general or surgical). On the contrary, our meta-analysis focused on cardiac surgery patients and provided a homogeneous structure. In addition, Holodinsky et al.[17] examined many perioperative factors, since they had a large patient group, unlike our study. As a result, sepsis, obesity, ileus, abdominal surgery and large volume fluid resuscitation were determined as risk factors for IAH in patients covering mixed ICU. Although IAH can be seen at a high rate in cardiac surgery, Holodinsky et al.[17] did not include this patient group in the analysis. However, there are findings similar to our analysis (e.g., sex and most comorbidities do not pose a risk). However, on the other hand, age, which we determined as a risk factor without showing heterogeneity, was not found to be a factor by these researchers.

The studies we included in our study found many different risk factors. There is no risk factor that these six studies usually agree on. Richer-Séguin et al.[12] determined BMI, mean pulmonary artery pressure, and CVP as risk factors. However, they concluded that age, sex, and intraoperative fluid balance were not risk factors. Kılıç et al.[10] showed that age, HT, CPB duration, lactate levels and erythrocyte use were risk factors. Mazzeffi et al.[6] did not observe any significant difference between the groups that developed IAH and those that did not. The researchers focused on urine neutrophil gelatinase-associated lipocalin (NGAL) in this study.[6] Iyer et al.[11] associated albumin, CVP, ACCT and CPB duration with an increase in IAP. Dalfino et al.[9] found that CVP, fluid balance, and baseline IAP were associated with the development of IAH as a result of stepwise analysis. Smit et al.[13] examined the effect of obesity on IAH in their study and showed that BMI was associated with IAH. In our analysis, where we determined four different factors, no factor other than sex could be examined by including all studies. Except for the analysis including HT and age, which we determined as risk factors, heterogeneity of up to 81.42% was observed in terms of other factors.

Nazer et al.[18] concluded in their prospective study of 50 patients that obesity (BMI >30 kg/m$^2$) was associated with the development of IAH in the postoperative period (OR=2.99; 95% CI: 1.92-3.53; p<0.001). The two studies we included in our analysis also reached similar conclusions.[12,13] In our study, we also observed that BMI was a risk factor for IAH. However, heterogeneity was very high among the studies (81.42%).

According to the findings obtained from our study, the studies showed heterogeneity in five out of 10 variables. We found that the inclusion of patients who were undergone off-pump and on-pump techniques in the same study was effective as the cause of heterogeneity for BMI and CPB duration. In addition, when we evaluated the findings in general, we observed that the analyses with numerical variables (in four out of five variables) had more heterogeneity. Therefore, we believe that this heterogeneity would decrease with the increase in the number of patients as well as the more homogenized patient groups.

In the studies we included in our study, different perioperative variables were examined. However, in order to be able to analyze these, variables examined by at least two studies were evaluated. Comparing these findings obtained in individual studies with the findings of our study, a significant difference was observed. While our study found age to be the only unchangeable factor, the other three factors including BMI, HT, and CPB duration were modifiable factors.

The main limitation to our study is the small sample size in the studies included. In addition, studies investigating variables other than sex and age were limited. There as a high heterogeneity, up to 81.42%; however, we could not perform meta-regression due to the limited numbers of studies (<10). Another important limitation was that the factors examined varied widely among individual studies.

In conclusion, we observed that age, hypertension, body mass index, and cardiopulmonary bypass duration are the risk factors for intraabdominal hypertension after cardiac surgery. However, we believe that the heterogeneity in these studies can be reduced with randomized-controlled trials among certain groups and more definitive findings can be obtained.

**Data Sharing Statement:** The data that support the findings of this study are available from the corresponding author upon reasonable request.

**Author Contributions:** All authors contributed equally to this article.

**Conflict of Interest:** The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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