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ORIGINAL ARTICLE

The incidence of myocardial infarction after lumbar spine surgery

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Abstract

Purpose As the population continues to age, the number of lumbar spine surgeries continues to increase. While there are many complications associated with lumbar surgeries, a myocardial infarction (MI) is a particularly devastating one. This complication is of considerable importance with mortality rates of postoperative MI documented between 26.5 and 70%. This study aimed to determine the relationship between lumbar surgeries, preoperative diagnoses (risk factors), and myocardial infarction.

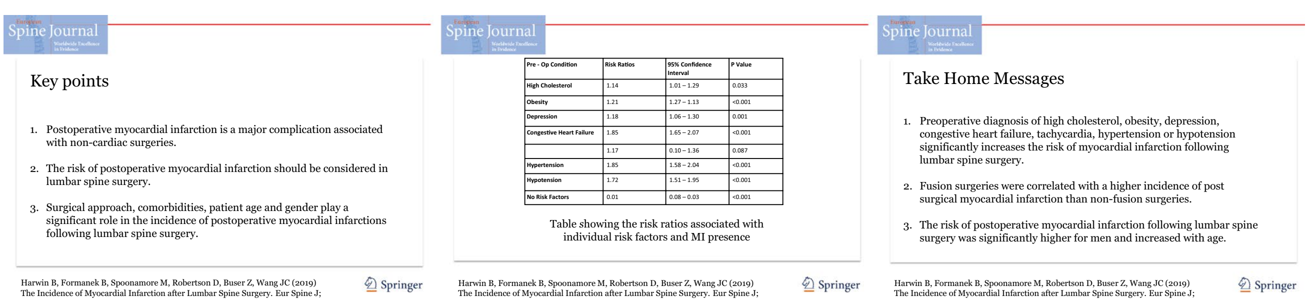
Methods Data from the Humana database (PearlDiver) were analyzed from 2007 to 2016. Patients undergoing lumbar spine surgeries were identified and stratified based on procedural approach, patient demographics, and preoperative risk factors. Each group was analyzed to determine the incidence and relative risk. Chi-square analysis was used to determine the significance.

Results A total of 105,505 patients who fit inclusion criteria were identified in the PearlDiver database between 2007 and 2016. A total of 644 patients (0.63%) experienced a postoperative myocardial infarction within 30 days of surgery. Patients undergoing fusion and non-fusion procedures showed significantly different rates of postoperative myocardial infarction (0.08% vs. 0.05%, $p < 0.01$). Male patients, older patients, and patients with a Charlson comorbidity index > 3 showed a considerable increase in incidence ($p < 0.01$). Furthermore, patients with preoperative risk factors (high cholesterol, obesity, depression, congestive heart failure, hypertension, and hypotension) exhibited risk ratios from 0.01 to 1.85 ($p < 0.01$).

Conclusion Preoperative risk factors, patient demographics, and procedure type had a significant effect on the incidence of postoperative myocardial infarction.

Graphic abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Myocardial infarction · Lumbar spine · Surgery · Database · Risk factors

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Introduction

The lumbar spine transmits compressive and shearing forces from the upper to lower body during daily activities [1]. The transmissibility of these forces is dependent on the mechanical integrity of the spine [1], and thus, pathologies of the lumbar spine can be particularly devastating. With a progressively aging population, there has been an increase in the number of spinal surgeries including lumbar spine [2, 3].

Although lumbar spine surgery has proven to be very successful in the management of patient discomfort [4], studies have demonstrated a noteworthy risk of cardiac complication following these surgeries [5–7]. An acute and potentially fatal cardiac complication is a myocardial infarction (MI). Myocardial infarction occurs when there is a lack of perfusion to myocardial cells, leading to cellular death [8]. A study by Thompson et al. [9] found myocardial infarction to be the most frequent postoperative cardiac complication. A study done at Mayo clinic from 1967 to 1968 followed 32, 877 patients for 1 week postoperatively and found a postoperative incidence of myocardial infarction of 0.22% [10]. The relationship between orthopedic procedures and postoperative myocardial infarction is inconsistent. Eagle et al. [11] stratified the risk of postoperative MI by surgical type and showed orthopedic procedures (hip, knee, leg, and ankle) to have an incidence of < 1%. However, Huddleston et al. showed hip surgeries to have an incidence of postoperative MI of greater than 10%. Fineberg et al. [12] utilizing the NIS database found that 0.67% of lumbar surgical patients experienced perioperative cardiac complication [4]. No study, however, has looked specifically at the relationship between lumbar spine surgery and myocardial infarction. Postoperative myocardial infarction has a documented postoperative MI mortality rate between 26.5 and 70% [13, 14].

The objective of this study was to analyze the overall rate of myocardial infarction in patients within 30 days of undergoing various lumbar surgeries. Furthermore, this study aimed to determine whether preoperative risk factors increase the risk of postsurgical myocardial infarction.

Materials and methods

Our hypothesis was that comorbidities would increase the chance of postoperative myocardial infarctions following lumbar spine surgery. We also hypothesized that surgical approach, gender, and age would play a significant role in postoperative myocardial infarction rate. Humana insurance database within PearlDiver Inc. was analyzed from 2007 through 2016. During this period, the Humana database contained 20.9 million patients with approximately 2 million patients entering the database annually. Medical diagnoses were searched using the *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* for diagnoses made from 2007 to 2016 as well as the *International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM)* for all diagnoses made from quarter 4 of 2015 through 2016. The database catalogs medical procedures using *Current Procedural Terminology (CPT)* codes.

The Humana database was analyzed from quarter 1 (Q1) of 2007 through Q3 of 2016. ICD and CPT codes of interest were used to search through the database and identify patients who met inclusion criteria for the study (Tables 1, 2). Patients were initially stratified into three groups based on the types of lumbar spine procedures: anterior fusion, posterior fusion, and non-fusion procedures (Table 1). Patients in the anterior fusion group were selected according to CPT codes for anterior or anterolateral approach. Patients in the posterior fusion group were selected according to CPT codes for lumbar fusion procedures with a posterior, posterolateral, or lateral extracavitary approach. Patients in the non-fusion group were selected according to CPT codes for laminectomy, laminotomy, and decompression (Table 1).

In coding for the anterior fusion group, CPT codes for posterior fusion groups were used as an exclusion parameter. Accordingly, CPT codes for the anterior fusion group were used as an exclusion parameter for the posterior fusion group. In the non-fusion group, CPT codes for the anterior and posterior fusion groups were included as an exclusion parameter. Patients with both anterior and posterior fusion approaches were excluded from these strictly defined groups. However, these multi-procedural patients were included in our total calculations of lumbar procedures.

Myocardial infarctions were identified using *ICD-9-D* codes and *ICD-10-D* codes (Table 2) and were only included in the study if they occurred within 30 days of surgery. The temporal distribution of postoperative myocardial infarctions was analyzed looking at total incidences at 24 h, 72 h, 7 days, and 30 days postoperatively.

Risk factors included high cholesterol, obesity, depression, congestive heart failure, tachycardia, hypertension, and hypotension. Patients were selected for each group by using appropriate *ICD-9-D* codes and *ICD-10-D* codes (Table 2). All patients must have received these diagnoses prior to undergoing lumbar surgery in order to be included in each group, respectively.

Table 1 CPT codes utilized to identify patients within the PearlDiver database

Procedure	CPT code
Anterior fusion	CPT-22558, CPT-22586
Posterior fusion	CPT-22533, CPT-22612, CPT-22630, CPT-22633
Non-fusion	CPT-62380, CPT-63005, CPT-63012, CPT-63015, CPT-63030, CPT-63047, CPT-63056

Patients with listed CPT codes were placed in the corresponding procedure groups (left column)

Table 2 Diagnoses with corresponding ICD-9-CM codes and ICD-10-CM codes

Diagnoses	ICD-9-CM codes	ICD-10-CM codes
Myocardial infarction	ICD-9-D-4100:ICD-9-D-4109	ICD-10-D-I210:ICD-10-D-I214, ICD-10-D-219
High cholesterol	ICD-9-D-2720, ICD-9-D-2722, ICD-9-D-2724	ICD-10-D-E780, ICD-10-D-E782, ICD-10-D-E784:ICD-10-D-E785
Obesity	ICD-9-D-27800:ICD-9-D-27802	ICD-10-D-E660, ICD-10-D-E661, ICD-10-D-E662, ICD-10-D-E668, ICD-10-D-E669
Depression	ICD-9-D-2963, ICD-9-D-3004, ICD-9-D-311	ICD-10-D-F330:ICD-10-D-F334, ICD-10-D-F338, ICD-10-D-F339, ICD-10-D-F341
Congestive heart failure	ICD-9-D-4280	ICD-10-D-I5020:I5043
Tachycardia	ICD-9-D-7850	ICD-10-D-R000
Hypertension	ICD-9-D-4010, ICD-9-D-4011, ICD-9-D-4019	ICD-10-D-I10
Hypotension	ICD-9-D-4581, ICD-9-D-4588, ICD-9-D-4589	ICD-10-D-I950, ICD-10-D-I958, ICD-10-D-I959

These ICD codes were used to identify patients within the PearlDiver database with preoperative diagnoses of interest

Patients were further stratified by sex and age. Additionally, patients were grouped according to whether their Charlson comorbidity index (CCI) score was below or above 3 [15]. We chose to use a CCI of 3 to dichotomize this group because this same subdivision was used in other studies that used CCI score as a prognostic indicator of myocardial infarctions [16].

The total incidence of myocardial infarctions was calculated for each surgical approach (anterior fusion, posterior fusion, and non-fusion). Differences in incidence were determined according to demographic factors, and risk ratios were determined for preoperative diagnoses.

Statistical analysis was performed using R statistical program through PearlDiver. Chi-square analysis was used to identify the significance of surgical approach, individual risk factors, and patient attributes on postoperative myocardial infarction incidence. 95% confidence intervals (CI) were calculated for all risk ratios by using an alpha level of $p \leq 0.05$.

Results

Using the PearlDiver Inc. database, a total of 105,505 patients who fit inclusion criteria were identified. Of these patients, a total of 664 developed a myocardial infarction within 30 days of the surgery (0.63%). Three thousand thirty-four of these patients met inclusion criteria for the anterior fusion group, 42,573 met inclusion criteria for the posterior fusion group, and 54,043 met inclusion criteria for the non-fusion group. Five thousand eight hundred fifty-five patients underwent multi-approach lumbar procedures. Twenty-six patients from the anterior fusion group (0.86%), 325 patients from the posterior fusion group (0.76%), and 246 patients from the non-fusion group (0.46%) suffered from myocardial infarction within a year (Fig. 1). The difference in incidence rates between the surgical groups was statistically significant (p value < 0.01); however, no significant difference was detected between the fusion groups (p value > 0.05). When total fusion (0.77%) was compared with non-fusion

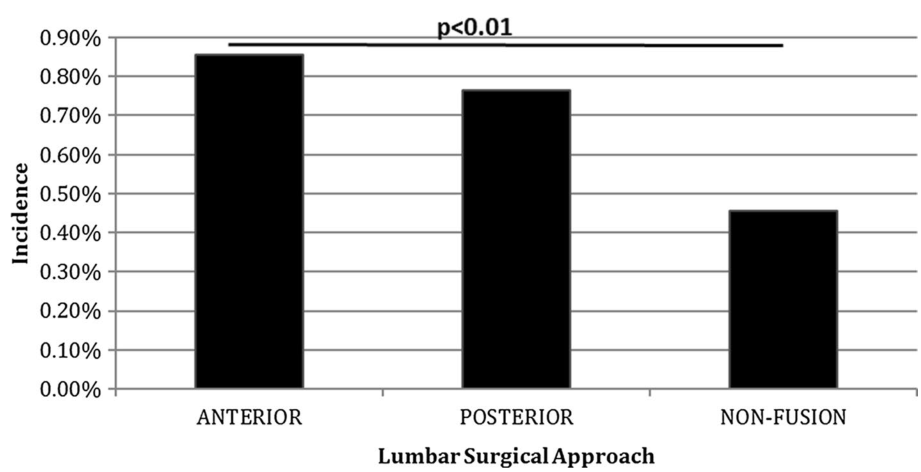

Fig. 1 Graphical representation of incidence of postoperative MI for patients who underwent anterior fusion, posterior fusion, and non-fusion lumbar spine surgeries. While significance was exhibited between all the three groups using chi-square analysis ($p < 0.01$), no significance was detected between anterior and posterior fusion groups

(0.46%), a statistically significant difference was detected with a p value < 0.001. The relative incidences of postoperative myocardial in these three surgical groups are represented graphically in Fig. 1.

Looking at the temporal distribution of postoperative myocardial infarctions, 323 patients (48.64%) experienced a myocardial infarction within 24 h of surgery and 380 patients (57.23%) by 72 h postoperatively. At 1 week postoperatively, 471 (70.93%) experienced a myocardial infarction (Fig. 2).

Fifty-one thousand five hundred fifty-three men (48.86%) and 53,952 women (51.14%) fit inclusion criteria. Three hundred seventy-three men experienced (0.72%) postoperative myocardial infarction, while 291 women experienced postoperative myocardial infarction (0.54%). Men were 1.31 times more likely to experience a postoperative MI than women (p value of 0.0011, Fig. 3).

Eighty-two thousand nine hundred thirty-five patients with a CCI ≤ 3 underwent lumbar surgery with 318 (0.38%) experiencing a myocardial infarction within 30 days. A total of 22,570 patients with a CCI > 3 underwent lumbar surgery with 346 (1.53%) suffering from a myocardial infarction within 30 days ($p < 0.001$). When compared to the CCI ≤ 3 group, the CCI > 3 group had a risk ratio of 1.78 with a 95% CI providing a range of 1.65–2.05.

Patients were further stratified by age: patients aged 50–59, patients aged 60–69, patients aged 70–79, patients aged 80–89, and patients aged 90 years and older. These age-groups had a MI incidence of 0.30%, 0.62%, 0.77%, 1.19%, and 1.87%, respectively (Fig. 4). Due to privacy limitations (suppression policy) of PearlDiver, Inc., the number of patients who suffered from myocardial infarction between ages 0 and 50 could not be determined within the Humana database (between 1 and 10). Thus, this age range was omitted from the age-based analysis.

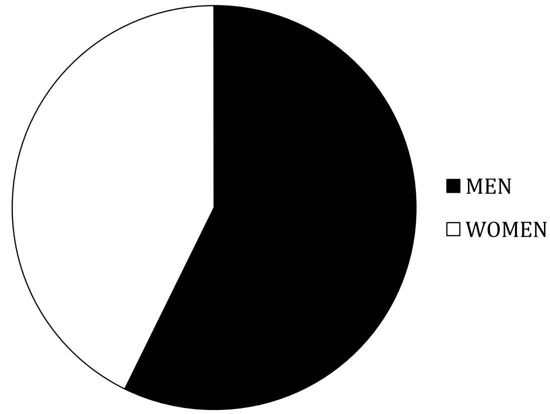

Fig. 3 Distribution of myocardial infarctions following lumbar spine surgery in a population equally stratified by gender

Isolated risk factors were analyzed to determine their relative risk, and it was found that all identified risk factors yielded a statistically significant effect (p value < 0.01, Table 3). Table 3 exhibits the identified preoperative risk factor and the associated relative risk of a postoperative MI when compared to those without the identified risk factor. Due to privacy limitations (suppression policy) of PearlDiver, Inc., the precise number of patients without any risk factors who had a MI postoperatively could not be determined.

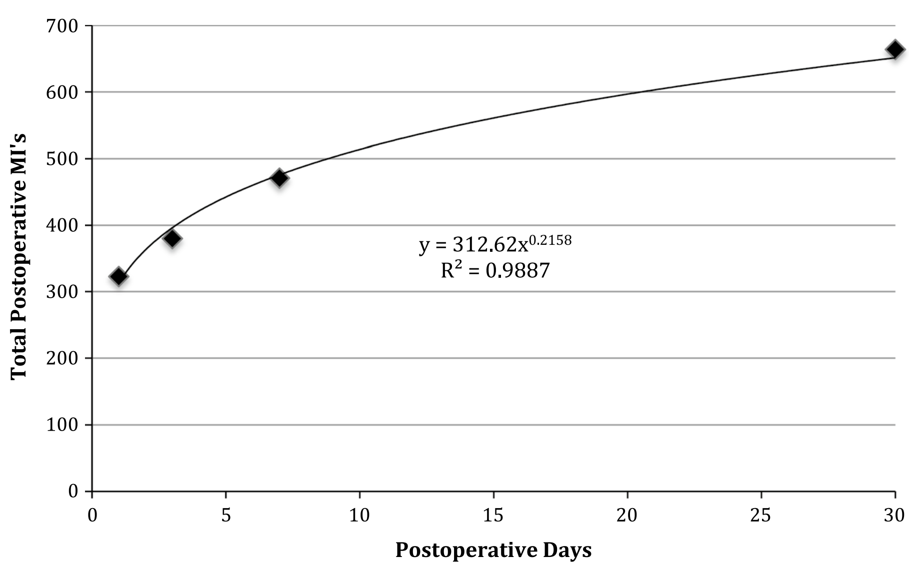

Fig. 2 Accumulated amount of postoperative MIs as a function of days after surgery

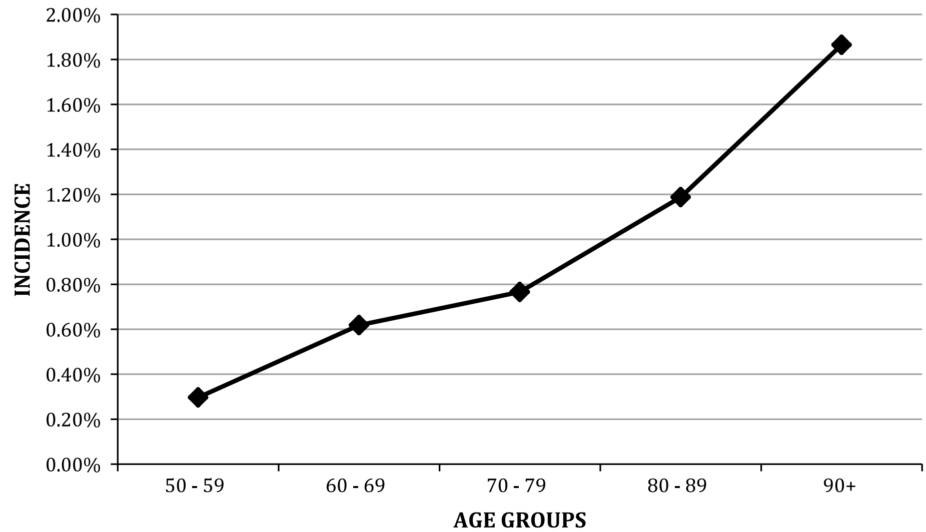

Fig. 4 Representation of the incidence of myocardial infarction as a function of age, which exhibits a strong relationship between age and postoperative myocardial infarction. Patients under 60 had a postoperative MI rate under 0.4%, while patients over 90 years old had a postoperative MI rate above 1.8%

Table 3 Risk ratios associated with individual risk factors and MI presence

Pre-op condition	Risk ratios	95% confidence interval	*p* value
High cholesterol	1.14	1.01–1.29	0.033
Obesity	1.21	1.27–1.13	< 0.001
Depression	1.18	1.06–1.30	0.001
Congestive heart failure	1.85	1.65–2.07	< 0.001
	1.17	0.10–1.36	0.087
Hypertension	1.85	1.58–2.04	< 0.001
Hypotension	1.72	1.51–1.95	< 0.001
No risk factors	0.01	0.08–0.03	< 0.001

Significant differences were detected among all listed groups

Discussion

Myocardial infarctions can be devastating cardiac events, with postoperative myocardial infarction mortality rates reported between 27 and 70% [13, 14]. In the current study, the incidence of postoperative myocardial infarction was 0.63%. Patients undergoing fusion surgeries had an incidence of 0.77%, while patients undergoing non-fusion lumbar procedures had an incidence of 0.45% (p value < 0.001). One of the possible explanations for the higher incidence of MI in fusion groups could be due to the type of surgery (complexity, number of levels, and surgical time) and because potentially patients in the fusion groups had higher incidence of risk factors. Future studies delineating these differences are needed.

Of the recorded myocardial infarctions, 48.64% occurred within 24 h of surgery, 57.23% occurred within 72 h of surgery, and 70.93% occurred within 1 week of surgery. Kikura et al. [17] showed postoperative myocardial infarction to peak the day after surgery and to decrease exponentially for the 30 days following surgery. Thompson et al. [9] and Von Knorring et al. [18] found that 85% of postoperative myocardial infarctions occurred within 72 h of surgery. Additionally, Thompson et al. [9] found that 8% of non-aortic myocardial infarctions occurred between 8 and 30 days postoperatively. These relative differences in findings may suggest a surgically specific temporal distribution of postoperative myocardial infarction. The data showed an exponentially decaying relationship with regards to myocardial infarction and postoperative time ($R^2 = .98867$), which is in agreement with Kikura et al. [5].

Men were more prone to myocardial infarctions than were women. This is in agreement with other studies that have shown the relative increased rates of myocardial infarctions in men when compared to women in general [10, 19]. Kikura et al. [17] showed men to have an odds ratio of 1.5 for postoperative myocardial infarction when compared to women, which was similar to the risk ratio of 1.31 in the current study.

A statistically significant increase in postoperative MI was exhibited with increasing age. A similar statistically significant trend was observed when dichotomizing patients based on CCI score. When compared to the CCI ≤ 3 group, the CCI > 3 group had a risk ratio of 1.78 with a 95% CI providing a range of 1.65–2.05. These findings are in agreement with Fineberg et al., who showed an increase in "cardiac events" with increasing age and CCI. It is important to remain cognizant of age- and CCI score-dependent incidence during preoperative planning.

High cholesterol, obesity, congestive heart failure, depression, hypertension, and hypotension all showed a statistically significant increase in the relative risk of myocardial infarction, which is in agreement with other studies [20–23]. Aside from congestive heart failure, hypotension proved to be the strongest risk factor for myocardial infarction. This finding is supported by other studies that show a strong correlation between hypotension (intraoperative) and myocardial infarction in non-cardiac surgery patients [24]. The significant increase in risk ratio with regards to each risk factor should be considered during preoperative planning.

It is important to address certain limitations of the study. The large sample size may have facilitated the detection of significant differences that may be due to random sampling distribution. Furthermore, risk ratio analysis did not account for possible confounding factors. It is also important to note that only documented MIs could be accounted for in the study, and thus, clinically silent MIs were not accounted for which have been reported to represent up to one-third of all MIs [25]. Finally, we did not follow the lifestyle of patients after their respective lumbar surgery, which may have played a significant role in their outcome.

Conclusion

Myocardial infarction is a serious complication that is associated with non-cardiac surgeries. Preoperative diagnosis of high cholesterol, obesity, depression, congestive heart failure, tachycardia, hypertension, or hypotension significantly increases the risk of myocardial infarction following lumbar spine surgery. This postoperative risk was significantly higher for men and increased with age. Fusion surgeries were correlated with a higher incidence of postsurgical myocardial infarction than non-fusion surgeries. With procedural, social, and medical stratification, this study may serve as a guideline for physicians in their consideration of surgical technique in conjunction with patient comorbidities.

Compliance with ethical standards

Conflict of interest None of the authors has any potential conflict of interest. Disclosures outside of submitted work: ZB- consultancy (past): Xenco Medical, AOSpine; Research support : SeaSpine (paid directly to institution); JCW - Royalties – Biomet, Seaspine, Amedica, DePuy Synthes; Investments/Options – Bone Biologics, Pearldiver, Electrocore, Surgitech; Board of Directors - North American Spine Society, AO Foundation (20,000 honorariums for board position, plus travel for board meetings), Cervical Spine Research Society; Editorial Boards - Spine, The Spine Journal, Clinical Spine Surgery, Global Spine Journal; Fellowship Funding (paid directly to institution): AO Foundation.

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