

Higher Charlson Comorbidity Index Scores are Associated With Readmission After Orthopaedic Surgery

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Abstract

Background The Charlson Comorbidity Index (CCI) originally was developed to predict mortality within 1 year of hospital admission in patients without trauma. As it includes factors associated with medical and surgical complexities, it also may be useful as a predictive tool for hospital readmission after orthopaedic surgery, but to our knowledge, this has not been studied.

Questions/purposes We asked whether an increased score on the CCI was associated with (1) readmission, (2) an increased risk of surgical site infection or other adverse events, (3) transfusion risk, or (4) mortality after orthopaedic surgery.

Methods A total of 30,129 orthopaedic surgeries performed between 2008 and 2011 without any orthopaedic surgery in the preceding 30 days were analyzed. International Classification of Diseases, 9th Revision codes were used to identify diagnoses, procedures, surgery-related adverse events, surgical site infection, and comorbidities as

listed in the updated and reweighted CCI. A total of 913 patients (3.0%) were readmitted within 30 days after discharge; in 393 (1.4%) patients adverse events occurred; 417 patients (1.4%) had a surgical site infection develop; 211 (0.7%) needed transfusions, and 56 (0.2%) died within 30 days after surgery. Ordinary least squares regression analyses were used to determine whether the CCI was associated with these outcomes.

Results The CCI accounted for 10% of the variation in readmissions. Every point increase in CCI score added an additional 0.45% risk in readmission for patients undergoing arthroplasty, 0.63% for patients undergoing trauma surgery, and 0.9% risk for patients undergoing spine surgery (all $p < 0.01$). The CCI was not associated with surgical site infection or other adverse events, but accounted for 8% of the variation in transfusion rate and 10% of the variation in mortality within 30 days of surgery.

Conclusions The CCI can be used to estimate the risk of readmission after arthroplasty, hand and upper extremity surgery, spine surgery, and trauma surgery. It also can be used to estimate the risk of transfusion after arthroplasty, spine, trauma, and oncologic orthopaedic surgery and the risk of mortality after shoulder, trauma, and oncologic orthopaedic surgery.

Level of Evidence Level IV, prognostic study. See the Instructions for Authors for a complete description of levels of evidence

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Hospital readmissions are used as an indicator of quality of care [3, 5, 24]. Readmissions are costly [13], and recent legislation introduced financial penalties for high risk-adjusted 30-day readmission for certain diagnoses by

establishing the Hospital Readmissions Reduction Program [6, 16, 19]. One center developed an intervention program to reduce readmissions after orthopaedic surgery [14].

There is a relationship between comorbidities and readmissions after orthopaedic trauma surgery [23, 35]. In orthopaedic surgery, comorbidities have been identified as predictors of mortality after arthroplasty, trauma surgery, and oncologic surgery [4, 9, 18, 20, 21, 25, 27, 36]. Complications after ankle fractures, spinal metastasis surgery, and knee or hip arthroplasty also are associated with comorbidities [2, 12, 31–34] as are infections after orthopaedic trauma, spine surgery, knee or hip arthroplasty [8, 17, 22, 36], and transfusion after knee or shoulder arthroplasty [12, 29].

The Charlson Comorbidity Index (CCI) [7] and its recent modification [26] are comorbidity-based measures developed to predict mortality within 1 year of hospital admission in patients without trauma. The updated CCI scores 12 comorbidities with various weightings giving a maximum score of 24 [26]. A higher CCI indicates a higher risk of death within 1 year. The CCI also has been evaluated as a predictor for outcomes after orthopaedic trauma surgery, postoperative adverse events after general surgery, and readmission for geriatric and general medicine patients [2, 9, 17, 30, 32–34, 37].

We sought to answer the following: Is an increased score on the CCI associated with (1) readmission, (2) surgical site infection or other adverse events, (3) transfusion risk, or (4) mortality after orthopaedic surgery?

Patients and Methods

The Research Patient Data Registry is a centralized clinical data registry covering a patient base of greater than 4.0 million insured and uninsured patients from Massachusetts General Hospital and Brigham Women's Hospital, Boston. It comprises diagnoses, medications, laboratory scores, procedures codes, demographic information (sex, age, race, marital status) and visit entries. We used the Research Patient Data Registry to identify patients having orthopaedic surgery. A total of 30,126 orthopaedic surgeries met the following inclusion criteria: (1) surgery performed between 2008 and 2011, and (2) no prior orthopaedic surgery within 30 days of the operation. The included surgeries were performed with an equal distribution of males and females, with the majority of the patients being between 40 and 59 years old (Table 1).

The International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) was used to code diagnoses and procedures. Surgeries were excluded if data were missing for diagnosis codes (194 cases) or procedure codes (1270 cases). Surgery-related adverse events and

Table 1. Demographics

Variables	Number	Percentage
Total operations	30,129	100
Sex		
Male	15,868	53
Age (years)		
≤ 19	2361	7.8
20–39	6027	20
40–59	11,667	39
60–79	8472	28
≥ 80	1602	5.3
Race		
White	26,581	88
Black	1085	3.6
Hispanic	1515	5.0
Asian	697	2.3
Other	251	0.83
Marital status		
Single	9885	33
Married	16,104	53
Divorced	1985	6.6
Widowed	1772	5.9
Other	383	1.3

infections (Appendix 1) and comorbidities as listed in the updated and reweighted CCI [26] (Appendix 2) also were classified using ICD-9 codes.

Statistical Analysis

Baseline characteristics of study patients were summarized with frequencies and percentages for categorical variables and as mean \pm SD for continuous variables. Factors significantly associated with readmission, adverse event, surgical site infection, transfusion, and mortality were assessed in bivariate analysis using Student's t-tests and chi-square tests (Table 2). Variables entered in these analyses were indicators for the ICD-9 procedure group, the surgeon, the patient's age group, sex, race and marital status, the timing of the operation, duration of operation, length of hospital stay, and orthopaedic subspecialty performing surgery (arthroplasty, foot and ankle, hand, shoulder, spine, sports, pediatrics, trauma, and oncology). For analysis of postoperative surgery-related adverse events and infections within 30 days of surgery, we excluded operations that were performed for surgery-related adverse events or infection within 30 days of another operation. Ordinary least squares regression analyses then were used to determine factors associated with

readmission, adverse event, surgical site infection, transfusion, and mortality within 30 days of discharge, from the CCI and the other explanatory variables, which were significantly related to our dependent variables in the bivariate analyses. We decided against using logistic regressions for computational reasons. The coefficient of the ordinary least squares regression indicates the direction of one unit increase of the response variable in relation to explanatory variable. The R-square means the percentage of the variance of the explanatory variable is accounted by the response variables in the model.

Results

Readmission

A total of 913 of 30,129 patients (3.0%) were readmitted within 30 days after discharge.

The CCI accounted for 10% of the variation in readmissions. Every point increase in CCI score adds an additional 0.45% risk in readmission for patients undergoing arthroplasty, 0.63% for patients undergoing trauma surgery, 0.90% risk for patients undergoing spine surgery (all $p < 0.001$), and -0.27% for patients undergoing hand and upper extremity surgery ($p = 0.092$) (Table 3). As a reference every year increase in age adds an additional 0.03% risk in readmission for all patients.

Surgical Site Infections and Other Surgery-related Adverse Events

Surgical site infections and other surgery-related adverse events within 30 days of surgery occurred in 393 of 28,604 (1.4%) (Table 4) and 417 of 29,678 (1.4%) (Table 5) patients, respectively. An increase in the CCI was not associated with changes in the likelihood of these events for all surgery types.

Table 2. Example of bivariable analysis*

Parameter	Readmission				p value
	No		Yes		
	Mean	Mean	Lower	Upper	
Duration of procedure (minutes)	79	133	-59	-50	< 0.01
Length of stay (days)	1.5	5.3	-4.6	-4.2	< 0.01

* Example of bivariable analysis of two explanatory variables on one of the response variables.

Blood Transfusion

Blood transfusion was prescribed after 211 of 30,129 (0.7%) orthopaedic surgeries. With every point increase in CCI score, the risk of transfusion was increased by 0.11% after arthroplasty ($p = 0.044$), 0.69% after spine surgery, 0.45% after trauma surgery, and 0.34% after oncologic surgery (all $p < 0.001$). The CCI explained 7.5% of the variation in blood transfusion after orthopaedic surgery (Table 6).

Mortality

Fifty-six of 30,129 patients (0.19%) died within 30 days after discharge. For every point increase in CCI score,

Table 3. Additional risk on readmission with every increasing CCI score (%) per orthopaedic subspecialty*

Orthopaedic subspecialty	Additional risk	95% CI		p value
		Lower	Upper	
Arthroplasty	0.45	0.0023	0.0066	< 0.001
Foot and ankle	-0.13	-0.006	0.0034	0.587
Hand and upper extremity	-0.27	-0.006	0.0004	0.092
Shoulder	-0.27	-0.007	0.0020	0.2630
Spine	0.90	0.0048	0.0132	< 0.001
Sports	-0.18	-0.006	0.0020	0.3590
Pediatrics	-0.82	-0.028	0.0118	0.421
Trauma	0.63	0.0030	0.0096	< 0.001
Oncology	-0.26	-0.01	0.0009	0.145
R-square	0.100			

* N = 30,129; CCI = Charlson Comorbidity Index.

Table 4. Additional risk on surgery-related adverse events with every increasing CCI score (%) per orthopaedic subspecialty

Orthopaedic subspecialty	Additional risk	95% CI		p value
		Lower	Upper	
Arthroplasty	0.013	-0.001	0.0017	0.87
Foot and ankle	0.077	-0.003	0.0042	0.66
Hand and upper extremity	-0.004	-0.002	0.0022	0.97
Shoulder	0.001	-0.003	0.0033	0.997
Spine	-0.031	-0.003	0.0027	0.838
Sports	-0.017	-0.003	0.0025	0.899
Pediatrics	-0.019	-0.014	0.014	0.979
Trauma	-0.053	-0.003	0.0019	0.664
Oncology	0.022	-0.002	0.0027	0.864

* N = 28,604 - only operations where adverse events were not present within 30 days before surgery were analyzed; CCI = Charlson Comorbidity Index.

Table 5. Additional risk on surgical site infections with every increasing CCI score (%) per orthopaedic subspecialty

Orthopaedic subspecialty	Additional risk	95% CI		p value
		Lower	Upper	
Arthroplasty	0.007	-0.001	0.0016	0.926
Foot and ankle	0.088	-0.003	0.0043	0.614
Hand and upper extremity	0.039	-0.002	0.0026	0.733
Shoulder	0.006	-0.003	0.0034	0.973
Spine	-0.021	-0.003	0.0028	0.891
Sports	-0.008	-0.003	0.0026	0.954
Pediatrics	-0.261	-0.017	0.0113	0.714
Trauma	0.044	-0.002	0.0028	0.712
Oncology	-0.089	-0.003	0.0016	0.482

* N = 29,678 - only operations where infections were not present within 30 days before surgery were analyzed; CCI = Charlson Comorbidity Index.

Table 6. Additional risk on transfusion with every increasing CCI score (%) per orthopaedic subspecialty

Orthopaedic subspecialty	Additional risk	95% CI		p value
		Lower	Upper	
Arthroplasty	0.11	0.000027	0.0022	0.044
Foot and ankle	-0.03	-0.003	0.002	0.797
Hand and upper extremity	-0.09	-0.002	0.0007	0.26
Shoulder	-0.03	-0.003	0.002	0.797
Spine	0.69	0.0048	0.009	< 0.001
Sports	-0.09	-0.003	0.0009	0.321
Pediatrics	-0.17	-0.012	0.0082	0.738
Trauma	0.45	0.0029	0.0061	< 0.001
Oncology	0.34	0.0017	0.0051	< 0.001
R-square	0.075			

N = 30,129; CCI = Charlson Comorbidity Index.

mortality increased 0.25% after shoulder surgery, 0.24% after trauma surgery, and 0.33% after oncologic surgery. The CCI explained 9.9% of the variation in mortality after orthopaedic surgery (Table 7).

Discussion

The ability to anticipate complications of treatment is essential to the effective practice of surgery. With the economic penalties associated with readmission after surgery with the Hospital Readmissions Reduction Program [6, 16, 19], there now are financial and professional incentives to improve our ability to anticipate complications of treatment. The CCI has been used as a predictor for

Table 7. Additional risk on mortality with every increasing CCI score (%) per orthopaedic subspecialty

Orthopaedic subspecialty	Additional risk	95% CI		p value
		Lower	Upper	
Arthroplasty	0.01	-0.00031	0.0005	0.667
Foot and ankle	-0.01	-0.001	0.0011	0.836
Hand and upper extremity	-0.02	-0.00095	0.0006	0.706
Shoulder	0.25	0.0013	0.0036	< 0.001
Spine	0.00	-0.001	0.001	0.953
Sports	-0.01	-0.001	0.0009	0.896
Pediatrics	0.05	-0.005	0.0055	0.847
Trauma	0.24	0.0016	0.0033	< 0.001
Oncology	0.33	0.0024	0.0042	< 0.001
R-square	0.099			

N = 30,129; CCI = Charlson Comorbidity Index.

adverse events [2, 9, 17, 30, 32–34, 37]. Our study addressed the association of comorbidities as measured by the CCI on readmission and adverse outcomes after orthopaedic surgeries. We evaluated the correlation between CCI and risk of readmission, surgical site infection, other adverse events, risk of transfusion, and mortality after orthopaedic surgery.

This study should be interpreted in light of several limitations. The data are from one registry representing a few years at two major teaching hospitals in the same area and therefore may not be generalizable. Our analyses on readmission did account for length of stay, although the relation of readmission and hospital stay has been questioned [11, 28]. We used ICD-9 codes to calculate the CCI (Appendix 2) and detect adverse events and surgical site infections (Appendix 1). ICD-9 codes may be inaccurate or incomplete in a large database, but the rate of errors seems acceptably low. The main drawback of using the CCI as a predictor of readmission or the other outcomes analyzed is that different conditions or combinations of conditions may lead to an equal index score. This blunt scoring system hinders the development of risk management protocols which should focus on specific conditions or interactions. In addition, we could not account for the severity of injury or complexity of surgery, both of which may influence surgery outcomes.

Readmission after surgery was associated with CCI for spine and trauma surgeries and arthroplasties but explained only a small amount of the variation in readmission. This is consistent with studies of medical patients [30, 37]. A retrospective study of readmission of general medicine patients admitted from the emergency department revealed a hazard ratio of 1.42 (95% CI, 1.07–1.89) for patients with a Charlson score of 2 to 4 and a hazard ratio of 1.93 (95%

CI, 1.37–2.73) for patients with a Charlson score higher than 4 [30]. A prospective study on geriatric patients revealed that 3.1% of the variation in readmission in their study-population was explained by the CCI [37].

In our study, the CCI was not related to repeat surgery for adverse events or surgical site infection. In other words, adverse events judged to be related to the surgery based on expert review were not related to the CCI. Prior studies that included medical adverse events found associations with the CCI. One 10-year study of patients undergoing primary THA revealed increased CCI score as a predictor of infection, dislocation, revision, perioperative fracture, neurologic injury, and thromboembolic events [33]. In another study, the risk of deep venous thrombosis or pulmonary embolism (DVT/PE) after surgery for ankle fracture was increased in patients with higher CCI scores [32]. An analysis of thromboembolic adverse events after THA and TKA exposed higher CCI score as a risk factor (odds ratio, 1.2; 95% CI, 1.1–1.4) for DVT/PE in patients undergoing TKAs but not for patients undergoing THAs [31, 34]. One retrospective study analyzing patients after oncologic orthopaedic surgery found the CCI was a predictor of medical complications (eg, pneumonia, respiratory failure) [2]. Higher CCI scores were found to significantly increase the risk of infection at 10 years after spine surgery (hazard ratio, 2.48; 95% CI, 1.93–3.19) [17]. Some comorbidities, in particular diabetes, have an important influence on infections after orthopaedic trauma surgery [8, 22].

CCI was associated with increased use of transfusion in patients undergoing arthroplasty, spine, trauma, or oncologic orthopaedic treatment in our study. Some studies of transfusion after orthopaedic surgery do not involve comorbidities in their risk analyses [1, 15], despite that some comorbidities (especially cardiovascular) commonly lead to increased need for transfusion. A prospective study of geriatric patients with primary hip or knee arthroplasty revealed coronary artery disease as a predictor of transfusion. The association between transfusion after shoulder arthroplasty and the number of comorbidities has been inconsistent [10, 12, 29].

In our study, the CCI was associated with a higher risk of death within 30 days of discharge for patients with trauma, undergoing shoulder surgery, or receiving oncologic treatment. The association of the CCI with mortality after trauma is consistent with prior studies in which higher in-hospital mortality was found in patients with hip fractures with higher CCI scores [9, 25].

This data set indicates that comorbidities as measured by the CCI have a significant influence on readmission, transfusion, and mortality after orthopaedic surgery, more so for certain subspecialties, but are not useful as a predictor of surgical site infection or surgery-related adverse events. To determine if these findings are generalizable,

multicenter studies could be useful, although our conclusions are drawn from a robust data registry providing considerable power. However, since multiple comorbidities or combinations have the same weight, the CCI may not be helpful in developing risk management protocols focused on specific conditions or interactions, for which a more precise tool is needed. Using Current Procedural Terminology codes and other methods, more detailed analyses for common procedures in each orthopaedic subspecialty could be made, for example, by addressing different kinds of arthroplasty or severity of injury.

Appendix 1. ICD-9 codes for variables used in this study*

Diagnosis	Corresponding ICD-9 codes
Surgical site infection	
Other specified local infections of skin and subcutaneous tissue	686.8
Unspecified local infection of skin and subcutaneous tissue	686.9
Unspecified infection of bone, site unspecified	730.90
Unspecified infection of bone, shoulder region	730.91
Unspecified infection of bone, upper arm	730.92
Unspecified infection of bone, forearm	730.93
Unspecified infection of bone, hand	730.94
Unspecified infection of bone, pelvic region and thigh	730.95
Unspecified infection of bone, lower leg	730.96
Unspecified infection of bone, ankle and foot	730.97
Unspecified infection of bone, other specified sites	730.98
Unspecified infection of bone, multiple sites	730.99
Infection and inflammatory reaction due to unspecified device, implant, and graft	996.60
Infection and inflammatory reaction due to internal joint prosthesis	996.66
Infection and inflammatory reaction due to other internal orthopedic device, implant, and graft	996.67
Infection and inflammatory reaction due to other internal prosthetic device, implant, and graft	996.69
Infected postoperative seroma	998.51
Other postoperative infection	998.59
Posttraumatic wound infection not elsewhere classified	958.3
Surgical adverse event	
Unspecified mechanical complication of internal orthopedic device, implant, and graft	996.40
Other mechanical complication of prosthetic joint implant	996.47

Appendix 1. continued

Diagnosis	Corresponding ICD-9 codes
Other mechanical complication of other internal orthopedic device, implant, and graft	996.49
Other complications due to internal joint prosthesis	996.77
Other complications due to other internal orthopedic device, implant, and graft	996.78
Other complications due to other internal prosthetic device, implant, and graft	996.79
Complications of unspecified reattached extremity	996.90
Complications of reattached hand	996.92
Complications of reattached finger(s)	996.93
Complications of reattached upper extremity, other and unspecified	996.94
Complication of reattached foot and toe(s)	996.95
Complication of other specified reattached body part	996.99
Unspecified complication of amputation stump	997.60
Other amputation stump complication	997.69
Surgical operation with implant of artificial internal device causing abnormal patient reaction, or later complication, without mention of misadventure at time of operation	E878.1
Amputation of limb(s) causing abnormal patient reaction, or later complication, without mention of misadventure at time of operation	E878.5
Other specified surgical operations and procedures causing abnormal patient reaction, or later complication, without mention of misadventure at time of operation	E878.8
Unspecified surgical operations and procedures causing abnormal patient reaction, or later complication, without mention of misadventure at time of operation	E878.9

* Four- and five-digit codes are included under the respective three and four-digit codes; Additional coding information is available at: www.findacode.com/.

Appendix 2. Comorbidities as listed in the updated CCI with corresponding ICD 9 codes as used in this study*

Diagnosis	Corresponding ICD9 codes
Congestive heart failure	398.91, 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 425.4–425.9, 428.x
Dementia	290.x, 294.1, 331.2
Chronic pulmonary disease	416.8, 416.9, 490.x–505.x, 506.4, 508.1, 508.8
Rheumatologic disease	446.5, 710.0–710.4, 714.0–714.2, 714.8, 725.x

Appendix 2. continued

Diagnosis	Corresponding ICD9 codes
Mild liver disease	070.22, 070.23, 070.32, 070.33, 070.44, 070.54, 070.6, 070.9, 570.x, 571.x, 573.3, 573.4, 573.8, 573.9, V42.7
Diabetes with chronic complications	250.4–250.7
Hemiplegia or paraplegia	334.1, 342.x, 343.x, 344.0, 344.6, 344.9
Renal disease	403.01, 403.11, 403.91, 404.02, 404.03, 404.12, 404.13, 404.92, 404.93, 582.x, 583.0–583.7, 585.x, 586.x, 588.0, V42.0, V45.1, V56x
Any malignancy, including leukemia and lymphoma	140.x–172.x, 174.x–195.8, 200.x–208.x, 238.6
Moderate or severe liver disease	456.0–456.2, 572.2–572.8
Metastatic solid tumor	196.x–199.x
HIV/AIDS	042.x–044.x

* Four- and five-digit codes are included under the respective three and four-digit codes; additional coding information is available at: www.findacode.com/.

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