# A potential simple tool to estimate 90-day mortality after total hip arthroplasty: Comparison with established comorbidity measures based on 38,735 patients from the Swedish Hip Arthroplasty Register

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# Abstract

## Background and purpose

Current comorbidity coding algorithms i.e. Charlson Comorbidity Index (CCI), Elixhauser Score, and the RxRisk-V Score are complex with limitations. The more simple ASA classification has not been investigated with respect to its ability to predict mortality after total hip arthroplasty (THA). The aim of this study was to compare ASA with the diagnosed based CCI, and Elixhauser Score, and the prescription based RxRisk-V in regard to the risk of early postoperative mortality after THA, and try to find a potential simple prediction tool for the clinical setting.

## Patients and methods

We performed a nationwide retrospective cohort study analysing 38,735 patients who had received a THA due to primary osteoarthritis. Kaplan-Meier method was used to calculate unadjusted cumulative survival. Logistic regression models were fitted to calculate crude and adjusted odds ratios (OR) with 95% confidence intervals (CI). The performance of the logistic regression models was evaluated by its discrimination capacity using c-statistics. Our primary endpoint was death within 90 day after surgery.

## Results

Unadjusted cumulative 90-day survival was 99.7 (CI 99.68 to 99.78) and the number of deaths 115. The RxRisk-V Scoreperformed better than CCI and Elixhauser in predicting 90-day mortality (AUC= 0.66). ASA had an AUC of XXX. Best predictive performance was found for the combination model of ASA, age, gender, presence of heart infarction or renal disease for the last 12 months prior to THA surgery (AUC=).

## Interpretation

A less data demanding comorbidity measure, i.e. the suggested combination of ASA, age, gender, presence of heart infarction or renal disease, or even ASA alone, serves us just as well if not better than the commonly used complex coding algorithms in predicting early postoperative mortality after THA.

# Introduction

Comorbidity burden is associated with a poorer outcome after THA surgery on a population level, i.e. an increased risk of early postoperative mortality, an increased risk of revision([1](#_ENREF_1), [7](#_ENREF_7)) and poorer patient outcomes([1](#_ENREF_1), [8](#_ENREF_8)). But how do we measure comorbidity? In our clinical departments an easily applicable tool with few dimensions is needed. Comorbidity measures such as the American Society of Anesthesiologists physical status classification (ASA) are preferred. ASA is easy to use but has not been validated as a predictor of 90-day mortality after THA and ASA is known to have a high degree of internal variability. ([11](#_ENREF_11" \o "Haynes, 1995 #1351))

In research settings diagnosed based (or prescription based) coding algorithms are often used to obtain a comorbidity measure([9](#_ENREF_9)) (i.e. Charlson Comorbidity Index (CCI), Elixhauser Score, and RxRisk-V). These measures are based on existing data sources, i.e. in- and outpatient data and prescription data but are rather complicated to use with a need to combine information from several data sources. Repeated updates of weighting and revalidations of the scores have been necessary. This has resulted in numerous variations of the same score and hence a remaining uncertainty regarding interpretation of and comparison between different studies. Inacio et al recently performed a study where the ability of Charlson Comorbidity Index (CCI), Elixhauser Score, and RxRisk-V to predict mortality after THA and TKA was evaluated in a research setting([10](#_ENREF_10)).

Several universal and arthroplasty specific risk prediction tools of various complexity have been introduced but none has been broadly accepted.([12](#_ENREF_12))

In this study we aimed to investigate how the clinically widely used comorbidity measure ASA influence the risk of early postoperative mortality compared to the more complicated diagnosed based CCI and Elixhauser Score and the prescription based RxRisk-V. We also aimed to investigate the prediction value of each comorbidity measure and of their included dimensions separately, in order to find a potentially easily accessible yet usable prediction tool.

# Methods

## Study design and study population

We performed a nationwide retrospective cohort study (Figure 1). All patients operated between 2008 and 2013 for THA due to primary osteoarthritis from the Swedish Hip Arthroplasty Register (SHAR) were included. Only elective primary hip arthroplasty procedures were included in order to minimize the risk of selection bias.

Follow-up started on the date of surgery and ended on the day of death, emigration, or December 31st 2013, whichever came first. Only the first surgery was accounted for in bilaterally operated patients to avoid dependency issues. Adjustment was made for age, gender, socioeconomic background, and type of hospital. Ninety days mortality was the primary outcome measure.

## Sources of data

***The Swedish Hip Arthroplasty Register*** registers all patients undergoing THA in Sweden since 1979. The SHAR has a stable completeness of registration around 96-98% and has been validated repeatedly.([13-15](#_ENREF_13))

***Statistics Sweden*** is a state-owned registry collecting information on the entire Swedish population i.e. level of education, personal and family income. Thanks to the ten-digit personal identity number all Swedish citizens are assigned at birth, linkage between different Swedish official and medical databases is made possible.

***The Swedish National Patient Register*** was started in 1964. It contains information on medical comorbidities and admissions to hospital care for all individuals in Sweden. The positive predictive value of the Swedish National Patient Register is estimated around 90±5%, which indicates high validity of data.([16](#_ENREF_16))

## Comorbidity measures

***The Charlson Comorbidity Index*** (CCI) is a diagnose based coding algorithm used in research.([17](#_ENREF_17)) It was developed to quantify the influence of comorbidities on survival. In this study the original weighting and the weighting according to Quan were investigated. ([17](#_ENREF_17), [18](#_ENREF_18))

***The Elixhauser Score*** is also a diagnose based coding algorithm used in research. ([19](#_ENREF_19)) The Elixhauser Score is more detailed than the more commonly used CCI.

***The RxRisk-V Score*** is a prescription based coding algorithm used in research.([20](#_ENREF_20), [21](#_ENREF_21)) Prescription based comorbidity measures have been increasingly used over the last years. It has been argued that a prescription based measure would be more reliable than a diagnosed based measure, not having the same limitations such as incomplete or inaccurate coding.([22](#_ENREF_22), [23](#_ENREF_23))

***The American Society of Anesthesiologists physical status classification*** (ASA) is a six-category physical status evaluation system developed in 1941 and it has remained virtually unchanged([24](#_ENREF_24)). The ASA grade was included in the Swedish Hip Arthroplasty Register (SHAR) in 2008, which is why our study period begins that year. ASA is easily assessed in a clinical setting and has been compared to CCI previously but not in a THA population.([25](#_ENREF_25), [26](#_ENREF_26))

## Statistics

We adhered to the guidelines on statistical analyses of register data.([27](#_ENREF_27), [28](#_ENREF_28)) Means, medians and ranges were used to describe continuous data. 95% confidence intervals (CI) described estimation uncertainty. Categorical data were investigated by cross-tabulation and the Chi-square test. The Kaplan-Meier method was used to calculate unadjusted cumulative survival. In order to calculate crude and adjusted odds ratios (OR) with CI logistic regression models were fitted with adjustment for relevant factors i.e. age, gender, BMI (Body Mass Index), type of hospital, fixation method, comorbidity and socioeconomic position. Continuous variables were kept continuous when possible in order to strengthen the precision of the statistical analyses.([29](#_ENREF_29))

The performance of the logistic regression models was evaluated by its discrimination capacity using c-statistics where the AUC-value (Area Under the Curve) stands for the degree of predictability. We performed no imputation for missing data.

## Ethical approval

All patients registered in the SHAR have received written information about the register. Registered patients have been given the choice not to participate in the registry or associated research but written informed consent for participation was not obtained. This is in consistency with the Swedish Patient Data Law from 2009. Our ethical approval was obtained from The Regional Ethical Review Board in Gothenburg (2013: 360-13).

# Results

Participants and comorbidities:

After the selection process (Figure 1) 38,735 individuals between 18 and 100 years old who hade undergone THA due to primary OA were analysed. The mean age was 68,6 years (SD 10.11) and there were somewhat more women (56.2%) than men (43.8%).

The highest proportion of patients with multiple comorbidities (i.e. three or more) was identified by the RxRisk-V measure (69.9%). For the Charlson Comorbidity Index the proportion of three or more comorbidities was 3.3% and for the Elixhauser Score it was 5.0%.

A vast majority of patients had an ASA score below three (84.8%). Individuals with an ASA score of 5 and 6 were excluded since those values describe moribund individuals.

See Table 1 for more characteristics of the study population.

## Ninety day mortality after THA

Unadjusted cumulative 90-day survival was 99.7 (CI 99.68 to 99.78), number of deaths 115. We found that age (OR 1,1 [CI 1.05-1.11]) and gender (female gender adjusted OR 0.4 [CI 0.29-0.65] were associated with the adjusted risk of death. Crude values indicated an increased risk of 90-day mortality for all three comorbidity indexes. After adjustment was made only CCI and the clinical ASA score remained associated with an increased risk of 90-day mortality. Within the social background variables only being a widow/-er (adjusted OR 1.7[CI 1.05-2.74]) fell out statistically significant after adjustment. Crude and adjusted odd ratios for 90-day mortality with 95% confidence intervals are presented in Table 2.

## Prediction strength of investigated comorbidity measures

***The Elixhauser Score*** was better in predicting 90-day mortality than the included dimensions separately with a 90 d AUC=0.63(see Table 3A).

***The Charlson Comorbidity Index*** When examining the CCIs different dimensions we found that the total CCI performed better in predicting 90-day and one-year mortality than the included dimensions separately. The original weighting (90-d AUC=0.64) was somewhat better in predicting 90-day mortality than the weighting according to Quan (AUC=0.61). (See Table 3B.)

***The RxRisk-V Score*** performed better than diagnose based comorbidity measures (CCI and Elixhauser Score) in predicting 90-day mortality with an AUC=0.66. The RxRisk-V Score performed better in predicting 90-day mortality than the included dimensions separately. (See Table 3C.)

***The American Society of Anesthesiologists physical status classification***

ASA alone had a better prediction strength for 90-day mortality (AUC=0.70) compared to the Elixhauser Score, CCI and RxRisk-V.

***Age, gender, ASA score, presence of heart infarction or renal disease combined the last 12 months*** After trying combinations of dimensions included in the different comorbidity measures and clinically accessible data we found that the combination of age, gender, ASA score, presence of heart infarction and renal disease the last 12 months gave the best prediction strength for 90-day and one year mortality)(AUC =). (See Table 4 and Figure 2) . Adding socioeconomic variables such as education level and civil status increased marginally the predictive power to AUC=, an insignificant increase (p =). Adding BMI did not increase the predictive power (Supplementary Table X).

# Discussion

## The impact of comorbidity on early postoperative mortality after THA

In this nation wide cohort study we wanted to compare the performance of commonly used diagnosed based comorbidity coding algorithms (i.e. CCI and Elixhauser Score), an increasingly used prescription based comorbidity coding algorithm (i.e. RxRisk-V) with a clinically widely used comorbidity measures (i.e. ASA) with adjustment for other relevant factors such as age, gender and socioeconomic background. We found that the original CCI (AUC 0.64) performed somewhat better than the Elixhauser Score (AUC 0.62) in predicting 90-day mortality. The prescription based RxRisk-V Scoreperformed better than the diagnose based comorbidity scores (CCI and Elixhauser Score) in predicting 90-day mortality with an AUC of 0.66. This differs from earlier findings by Inacio where the RxRisk-V did not perform as well as the CCI and Elixhauser Score and where the AUC-values generally were higher than in our study.([10](#_ENREF_10)) The study population of our study was younger and included more women and we only included diagnoses and prescriptions registered one year prior to surgery, which perhaps could at least partly explain the differences in the results.

Comorbidities are known to influence the outcome after THA.([1](#_ENREF_1), [7](#_ENREF_7), [8](#_ENREF_8)) In order to include the effect of comorbidity in research different comorbidity measures are used; either diagnosed based or prescription based. However, these comorbidity measures are not used in clinical settings and, not seldom they demand a merge of information from several data sources. Patient administrative data are highly accessible to researchers but are known to be incomplete. Coding errors and underreporting of certain conditions are common.([9](#_ENREF_9))

ASA is a comparatively old comorbidity measure that has stayed the same since its introduction([24](#_ENREF_24)). ASA has been repeatedly compared to CCI but no consensus as to which one is superior has been reached and, to our knowledge, it has not been done in a selected THA population.([25](#_ENREF_25), [26](#_ENREF_26)) In our study ASA had a better predictive capacity with an AUC of 0.70 for 90-day mortality.

BMI is generally known to be associated with a higher risk of mortality and morbidity. ([30](#_ENREF_30))However, previous studies on primary THA cohorts have not been able to show a higher risk of mortality in obese patients, a result that is confirmed in our study (See Supplementary Table X).([31](#_ENREF_31)) An explanation could be that obese patients selected for THA are comparably healthy.

## The prediction strength

Risk prediction may be useful in the patient selection process, in the preoperative risk mitigation process of a patient and in research settings. A number of risk prediction tools for adverse outcomes after total joint replacements have been introduced on the market with various validation and performance measures. ([12](#_ENREF_12)) Using c-statistics we evaluated the prediction strength of different comorbidity measures intended for research, and their included dimensions, with that of a comorbidity measure intended for clinical use. Overall the predictive strength of the total index of the diagnose and prescription based measurements was better than the individual predictive strength of the included dimensions separately. ASA performed better than the more complex coding algorithms. This was also confirmed in exploratory analyses of 1 year mortality (Supplementary Table X).

We then wanted to find a combination of clinically easily accessible information that gave an even better predictive performance than ASA alone. The best predictive strength was found for a model including ASA score, age, gender, and presence of cardiac infarction or renal disease the last 12 months prior to THA surgery (AUC 0.81).

In regard to trauma outcome prediction tools are common and it is has been shown that a clinical evaluation tool with few variables included tend to have stronger prediction capacity than more complex ones.([32](#_ENREF_32)) Our results indicate that also for THA we should try to find risk prediction models not more detailed and complex but rather simpler and including the right variables. A risk prediction measurement of this kind would also have a smaller risk of coding errors etc. in research settings.

## Strengths and limitations

Strength of this study is that it is nationwide with a large cohort with a reasonable number of events. The sources of data have been shown to a have a high validity of data and the risk of missing data or cohort attrition was low. ([13-16](#_ENREF_13)) Limitations are the potential bias at different levels associated with observational data and the risk of coding errors as expected when dealing with patient administrative data. One could also criticize us for including ASA in our suggested combination of variables since it is a comorbidity measure in itself and hence there is a risk of “dubble measuring”. Our aim was to find a combination of easily accessible clinical data that gave us a good prediction capacity. We did not find a combination of variables excluding ASA-score that was close in predictive strength why we chose to include ASA.

It is important to make a distinction between explanatory research and prediction research. In the latter, prediction research, the investigated temporal context is another i.e. *futurum*. In order for a risk factor to be considered a predictor, the investigated effect needs to be tested in a different sample of individuals to capture the “*futurum*” aspect. This has not been done. Hence it is only with extreme caution we can extrapolate our findings into predictions in the clinical setting. Our results indicate that, in research, a less data demanding comorbidity measure, i.e. the suggested combination of age, gender, ASA score, presence of heart infarction or renal disease for the last 12 months, serves us just as well if not better than the commonly used diagnose based or prescription based coding algorithms. It would be interesting to evaluate the effect on adverse events and revision rate within 2 years in the Swedish setting and validate the combination comorbidity measure on other populations in the future.

## Conclusion

Our results of this nationwide cohort study indicate that a less data demanding comorbidity measure, such as the ASA score combined with age, gender, presence of heart infarction or renal disease for the last 12 months prior to THA surgery, or even ASA alone, serves us just as well if not better than the commonly used more complex diagnose based or prescription based coding algorithms in predicting early postoperative mortality after THA.

## Contribution of authors

AG, NH: initiated the study and managed the ethical review board application. EB, SN and AG performed the statistical analyses. GG: Assisted in preparing the review board application. AG drafted the manuscript. AG, EB, SN, NH and GG took part in designing the study and editing the manuscript.

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