Variation in severity-adjusted resource utilization and outcome in intensive care units

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Statistical analysis plan

We describe the study population by frequencies (n), percentages (%), means and standard deviations (SD), medians and interquartile range (IQR). Differences across ICU categories are tested by an analysis of variance and a chi-squared test. We investigate an interaction effect between SAPS categories and calendar year on the number of ICU admissions using a Poisson regression model. To calculate non-cost SRU based on LOS and TISS for each ICU we first calculate the expected overall resource use by calculating average LOS and TISS per one hospital survivor, by SAPS category. Then we calculate for each ICU the expected resource use for each SAPS category by multiplying the number of surviving patients by the expected overall resource use. This product is the expected LOS and TISS that the "average" ICU would use to "produce" the number of surviving patients (Rothen HU et al. (2007)[https://doi.org/10.1007/s00134-007-0690-3]). Units with no observed survivor were set to have 0.001 survivor per observed deaths. To calculate non-cost SRUR for a specific ICU we divide the sum of the observed LOS and TISS by the expected LOS and TISS. This SRUR reflects the severity-adjusted, observed to expected ratio of resources (estimated as LOS and TISS in the ICU) used by a specific unit. (Rothen HU et al. (2007)[https://doi.org/10.1007/s00134-007-0690-3]). To calculate SRUR based on direct costs (costSRUR) we calculated the expected average direct costs per one LOS or TISS for all units by year. We then calculated the expected costs based on LOS and TISS by multiplying the expected LOS and TISS for each unit and SAPS category by the expected expected average direct costs per one LOS or TISS. The costSRUR based on costs from LOS or TISS is obtained by dividing the observed direct costs by the expected costs. We calculate the expected number of deaths from a risk prediction model and calculate the SMR by dividing the observed number of deaths by the expected number of deaths for each ICU and SAPS category. To investigate the effect of SMR on SRUR and costSRUR we fit a Gaussian linear regression, both unstratified and stratified by hospital typology, for each year and report estimated slope coefficients with 95% confidence intervals (CI).

We use hierarchical regression models to investigate ICU-related factors related to SRUR (LOS, TISS and costLOS and costTISS) outcomes. In brief, hierarchical regression models pool information across ICUs, which provides 'improved' effect estimates by a shrinkage to the mean effect (Gelman A, Hill J: Data Analysis Using Regression and Multilevel/Hierarchical Models, https://doi.org/10.1017/CBO9780511790942). We tested the null hypothesis of no linear time trend (i.e. null hypothesis $H_0{:}\beta=0$ and alternative hypothesis $H_a{:}\beta\neq0$, where β is the slope coefficient from a Gaussian hierarchical linear regression $Y_i=\beta_0+\beta YEAR+u_i+\epsilon_i$, where i indicates the ith ICU und u_i is a ICU-specific random effect), where the outcome variable is the logarithm of SRUR and SMR and calendar year is a linear continuous predictor. We model SRUR and costSRUR assuming a log-link Gamma distribution and SMR using a Poisson distribution with observed LOS, TISS, direct costs and number of non-survivors as outcome variables and the expected outcomes as offset variable with an unstructured random effect on ICU level (Verburg et al. 2014) [https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0109684#s4] (Moran and Solomon BMC Medical Research Methodology 2012,12:68)[http://www.biomedcentral.com/1471-2288/12/68]. We a priori select the following ICU-related variables of interest as fixed effects in the model

- Hospital typology

and

- Calendar year,
- Cardiac surgery performed in hospital (yes/no),
- Neurosurgery performed in hospital (yes/no),
- Nurses/doctors,
- Nurses/beds,
- Total number of beds,
- Readmissions/total admissions,
- Admissions/beds,
- Availability of a specialist 24/7 (yes/no),
- Medical emergency team (yes/no),
- FTE physicians,
- Organisation type (independent or not),
- Median SAPS-II,
- SMR.

Note that fitted a model with hospital typology alone, because hospital typology is highly correlated with other variables. Continuous variables were standardised, i.e. variables were centered and effects are expressed per one standard deviation increase.