Supplementary Material

Supplementary analysis of the association between time since arrival of an additional concurrent surgical patients and time to surgery for hip fracture patients.

To identify the most salient time window for counting concurrent admissions for acute surgery we analyzed the association between time since admission of concurrent surgical patients and time to surgery for the hip fracture patient. For each hip fracture patient, we made a smoothing spline approximation $a_i(t)$ of the hourly arrival rate of surgical patients within the 96 hours preceding the hip fracture patient's admission. These were used in a functional regression analysis[1] to compute the response $\beta(t)$ on time to surgery for the hip fracture patient of an additional surgical patient arriving at time t. The equation for this model is

$$\log\left(Time\ to\ surgery\ _{patient\ i}\right) = \int_0^{96} a_i(t)\beta(t)dt + \text{covariates} + \text{error}_i.$$

The following Stata code (StataCorp, College Station, Texas, USA) computes the spline coefficients for a restricted cubic spline approximation of $a_i(t)$ and performs the functional regression with bootstrapping. The number of concurrent surgical patients that arrived between n-1 and n hours prior is here denoted *surgical_admissions_nh*. These variables can be computed by a slight modification of the code (see below).

```
// Define spline nodes and number of nodes n
local n   = 5
local x1  = 0
local x2  = 24
local x3  = 48
local x4  = 72
local x5  = 96

local n1 = `n' - 1
foreach k of numlist 0/`n' { // Initialise spline coefficients
     gen X`k'=0
}
foreach j of numlist 1/96 {
     replace X0 = X0 + surgical_admissions_`j'h
     replace X1 = X1 + `j' * surgical_admissions_`j'h
     foreach i of numlist 1/`n1'{
          local   i1  = `i' + 1
          gen     nu1 = (`j' - `x`i'')^3
          gen     nu2 = (`j' - `x`n1'')^3
          gen     nu3 = (`j' - `x`n'')^3
          replace nu1 = 0 if nu1<0
          replace nu2 = 0 if nu2<0
          replace nu3 = 0 if nu3<0
          // Restricted cubic spline formula:
          replace X`i1' = X`i1' + surgical_admissions_`j'h*(nu1 - 1/(`x`n''-
`x`n1'')*(nu2*(`x`n''-`x`i'')-nu3*(`x`n1''-`x`i'')))/(`x`n''-`x1')^2
     drop nu*
```

```
        }
}
// Bootstrap, save for plotting results
bootstrap, reps(200) saving("bootstrap.dta",replace) cluster(id_1): xtreg lTTO s720
prev_adm GP_use woman age age2 X*, i(id_1) fe
```

The result of this analysis is shown in Supplementary Figure a, which shows that patients arriving less than 48 hours prior to the hip fracture patient add substantially to the time to surgery for the hip fracture patient. Earlier arrivals had a smaller impact. Patients admitted 39 hours prior to the hip fracture patient impacted time to surgery the most, with 2.2% additional time to surgery per additional admission (95% confidence interval 1.6 to 2.9).

1. **Ramsay J, Silverman BW**. *Functional data analysis (chapter 12)*. Springer-Verlag New York. 2005.

Stata code for computing concurrent patients who arrived less than 48 hours prior, for each hospital and hour in the dataset.

```stata
// data-file containing IN, OUT, hospital for all acute surgical patients
// Will now only be used to extract hospitals and dates
use "surgical_patients_in_out_hospital.dta", replace

// Generate list of time-points to compute on:
// For each whole hour in the data set, generate one line per hospital
replace IN  = .
gen virtual = 1 // Variable indicating a row which is not a patient

sum date
local mindate  = r(min)
local maxdate  = r(max)
local number_of_days = `maxdate' - `mindate' + 1

// Keep only one line per hospital
sort hospital
by hospital: keep if _n == 1
replace in_date = `mindate'

// Make one line per day per hospital
expand `number_of_days'

sort hospital
replace date = date[_n-1]+1 if hospital == hospital[_n-1]

// Expand each day and hospital with 24 hours
sort hospital date
expand 24
gen hour = 0
sort hospital date hour
replace hour = hour[_n-1] + 1 if hospital == hospital[_n-1] & date == date[_n-1]

replace IN  = mdyhms(month(date), day(date), year(date),hour,0,0)

// Add back the patient records
append using "surgical_patients_in_out_hospital.dta"

// Count surgical patients that arrived less than 48 hours before, and present at each IN-time-point
sort hospital IN
local proceed     = 1
local i           = 0
gen occupancy_48h = 0

while `videre' {
        local i = `i'+1
        // For each IN, count line n-i if correspoding to concurrent patient who arrived less than 48h prior
        by hospital:        gen X = (OUT[_n-`i'] > IN) & (IN-IN[_n-`i']<msofhours(48)) & (virtual[_n-`i']!=1)
        replace occupancy_48h     = occupancy_48h + X
        drop X

        // To control termination of the loop:
        by hospital:        gen X = ((IN-IN[_n-`i']) < msofhours(48))& (virtual[_n-`i']!=1)
        count if X
        local proceed = r(N)
        drop X
}
keep if virtual == 1
drop virtual

save "occupancy_per_hospital_and_hour", replace
```

Stata code for assembling the proportion of hospital activity occupied by recently admitted surgical patients and performing the analyses.

```stata
// Hip fracture patient records, containing hospital, in_date, in_hour, in_year,
//   holiday dummy, death date, woman, age, GP admissions,
//   previously admitted, average occupancy at 12:00 within month and hospital.

use "data.dta", replace

// indicator for doing within-analysis
gen week_day_holiday     = dow(in_date)
replace week_day_holiday = 0 if  holiday == 1
gen sixhour              = floor(in_hour/6)*6
egen id_1                = group(hospital in_year in_month week_day_holiday sixhour)


// Indicator of activity, measured at end of each six-hour interval
gen hour       = mod(sixhour+6,24)
replace date    = date + 1 if hour == 0
merge m:1 hospital date hour using "occupancy_per_hospital_and_hour"
keep if _merge  == 3
drop _merge
replace date    = date - 1 if hour == 0
gen Indicator   = occupancy_48h/occupancy_1200_month


// Parameters for Cox
generate sensor_date   = mdy(12,31,2016)
gen death_1            = 1 if death_date<sensor_date
replace sensor_date    = death_date if death_date<sensor_date
format sensor_date death_date in_date %td

// Make cubic splines with four knots
mkspline spl_x = Indicator, cubic nknots(4)

// Which levels of the indicators are compared to which reference level
// The list of levels is trimmed down to a size that can be handled,
//   removing observations <10th and >90th %tiles
levelsof Indicator, local(levels)
levelsof Indicator, local(levels2)
sum Indicator, d
local i = 1
foreach ii of local levels{
        local i = `i'+1
        if (`ii'> r(p90))|(`ii'< r(p10))|(mod(`i',10)>0){
                local levels2: list levels2 - ii
        }
}

local n: list sizeof levels2
di `n'

local reference = r(p50)

// 60-day mortality
stset sensor_date, failure(death_1) enter(time in_date) origin(in_date) exit(time in_date + 60)
stcox spl_x* s720 previously_admitted GP_consultations_2months woman age age2, strata(id_1)
quietly xblc spl_x*, covname(Indicator) at(`levels2') reference(`reference') eform generate(n_mort
estimate_mort lower_mort upper_mort),

// TTO: Time to operation
xtreg lTTO spl_x* s720 previously_admitted GP_consultations_2months woman age age2, i(id_1) fe
quietly xblc spl_x*, covname(Indicator) at(`levels2') reference(`reference') generate(n_TTO estimate_TTO
lower_TTO upper_TTO),
```
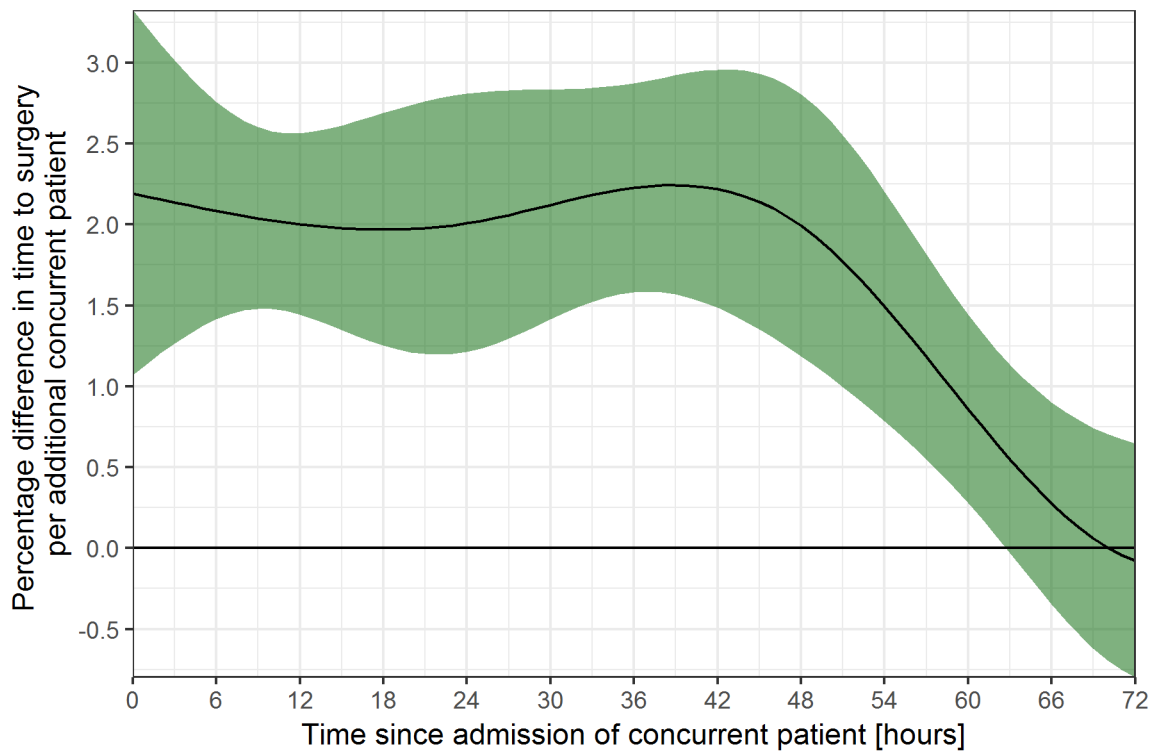
Figure a. Association between time since admission of an additional concurrent surgical patient and time to surgery for the hip fracture patient with 95% confidence interval. The x-axis shows the number of hours a concurrent patient had been present when the hip fracture patient was admitted. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. The number of patients in this analysis was 44,508.
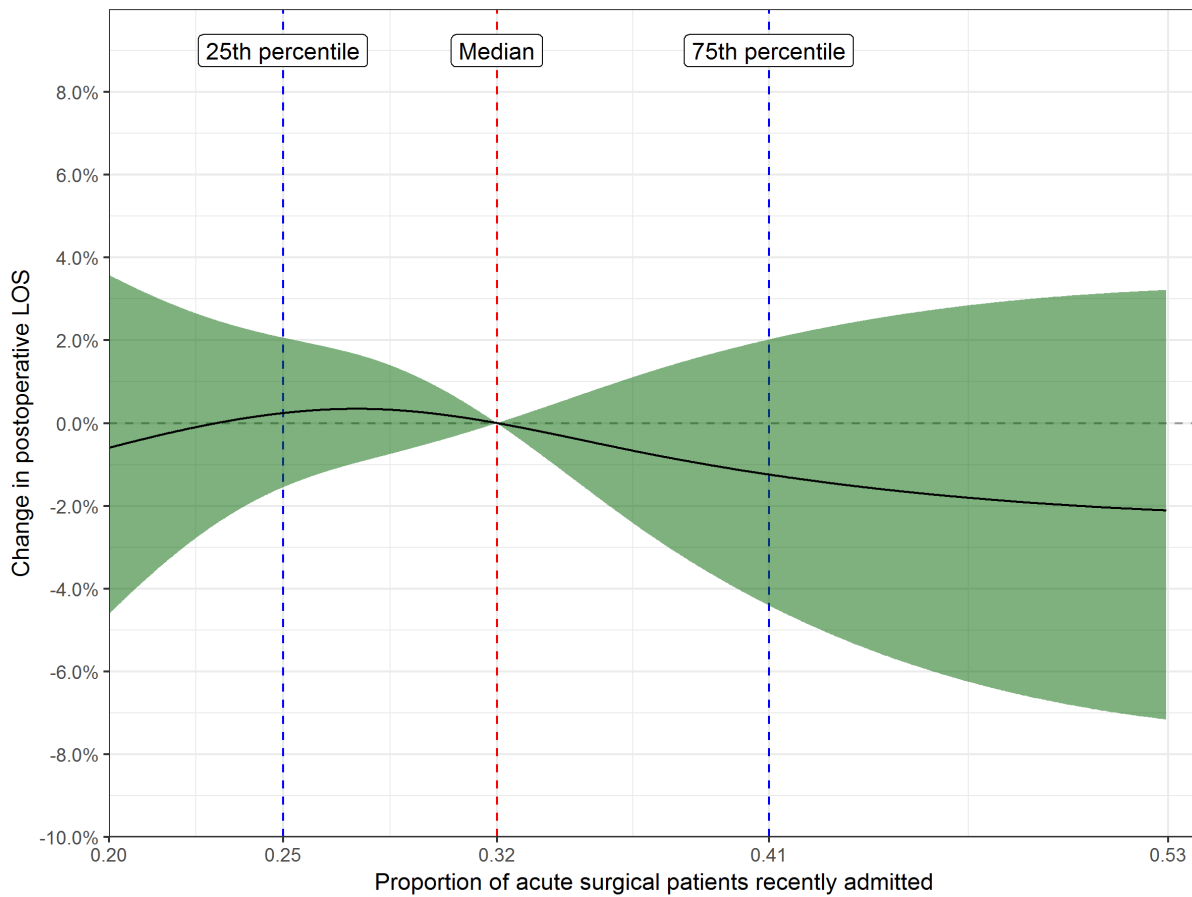
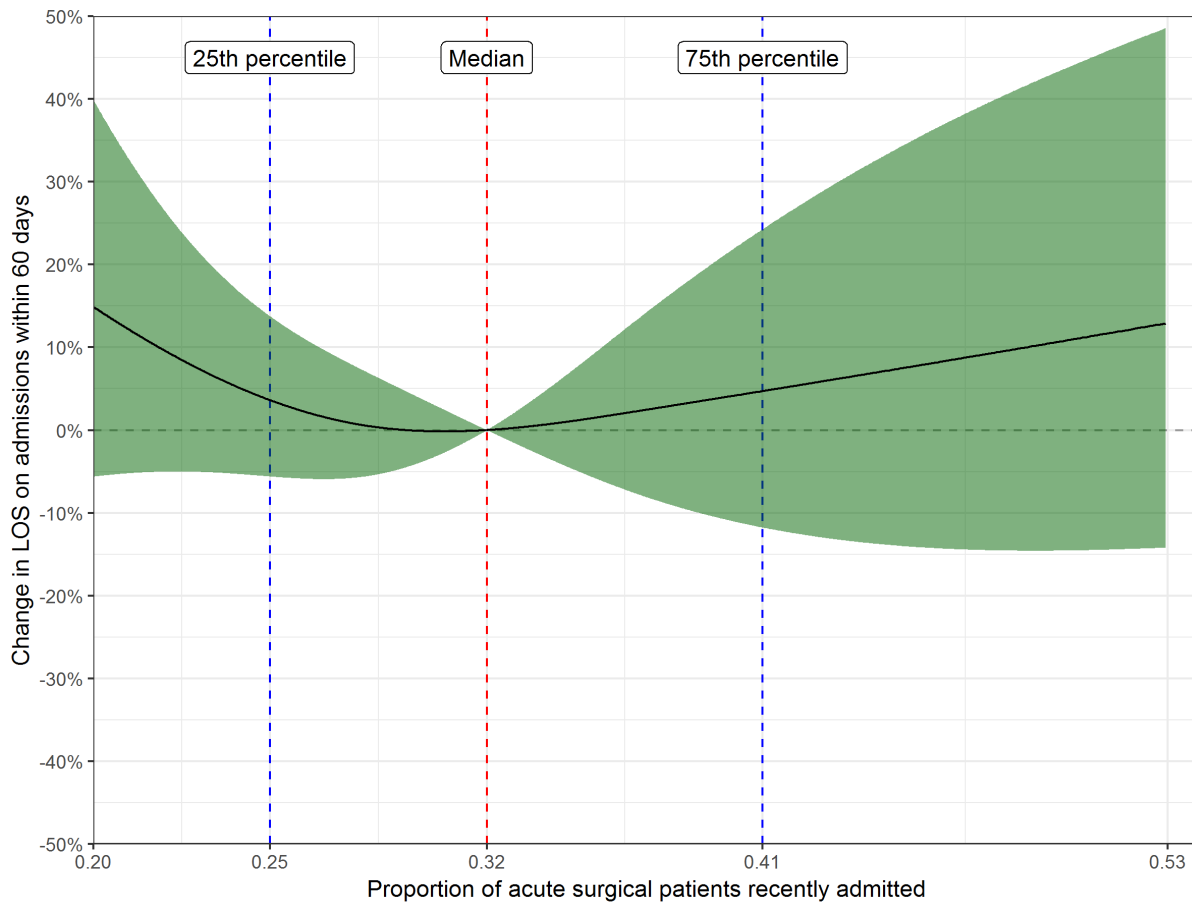**Figure b.** Association between the proportion of recently admitted surgical patients and postoperative length of hospital stay among hip fracture patients. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. The number of patients in this analysis was 65,097. LOS, length of stay.

Figure c. Association between the proportion of recently admitted surgical patients and length of hospital stays on subsequent admissions within 60 days. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. The number of patients in this analysis was 65,097. LOS, length of stay.
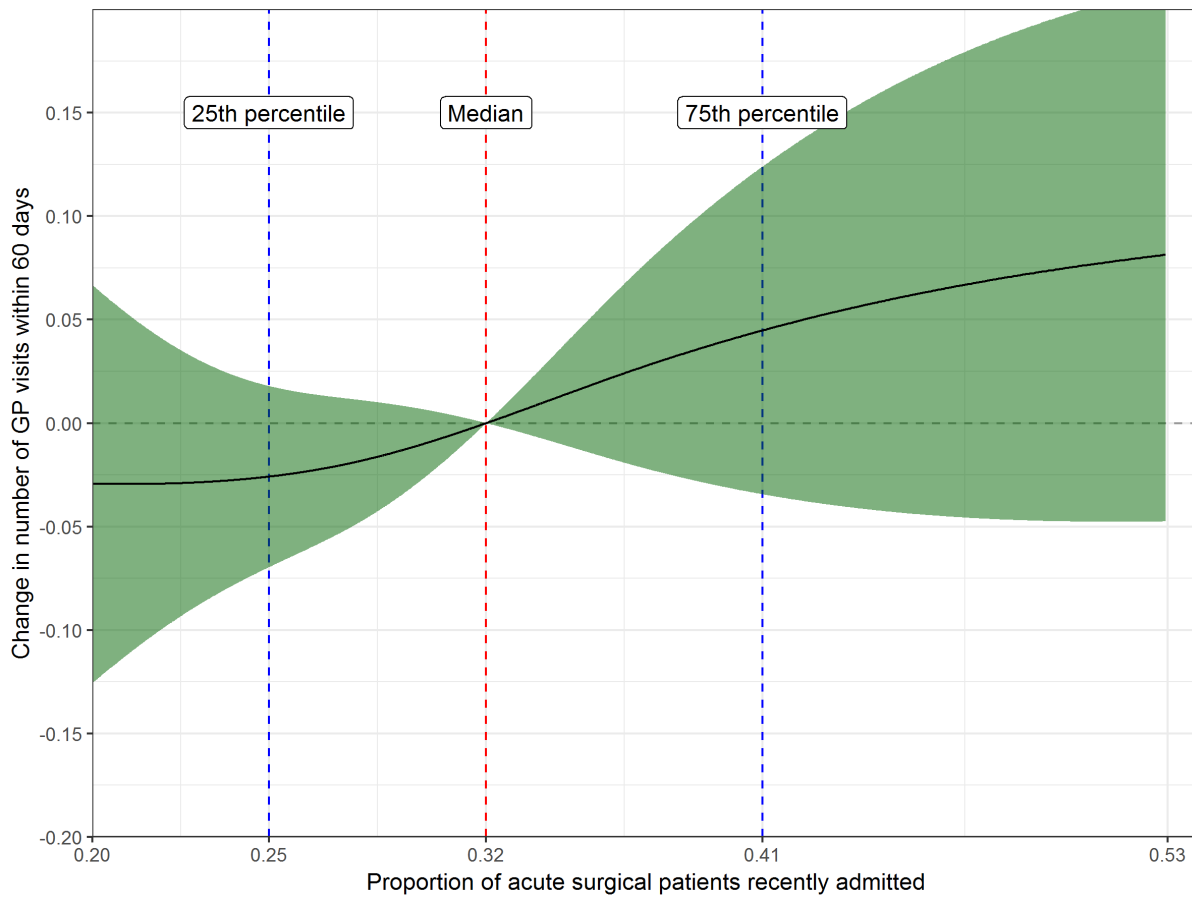
Figure d. Association between the proportion of recently admitted surgical patients and number of GP visits within subsequent 60 days. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner (GP) visits. The number of patients in this analysis was 65,097.
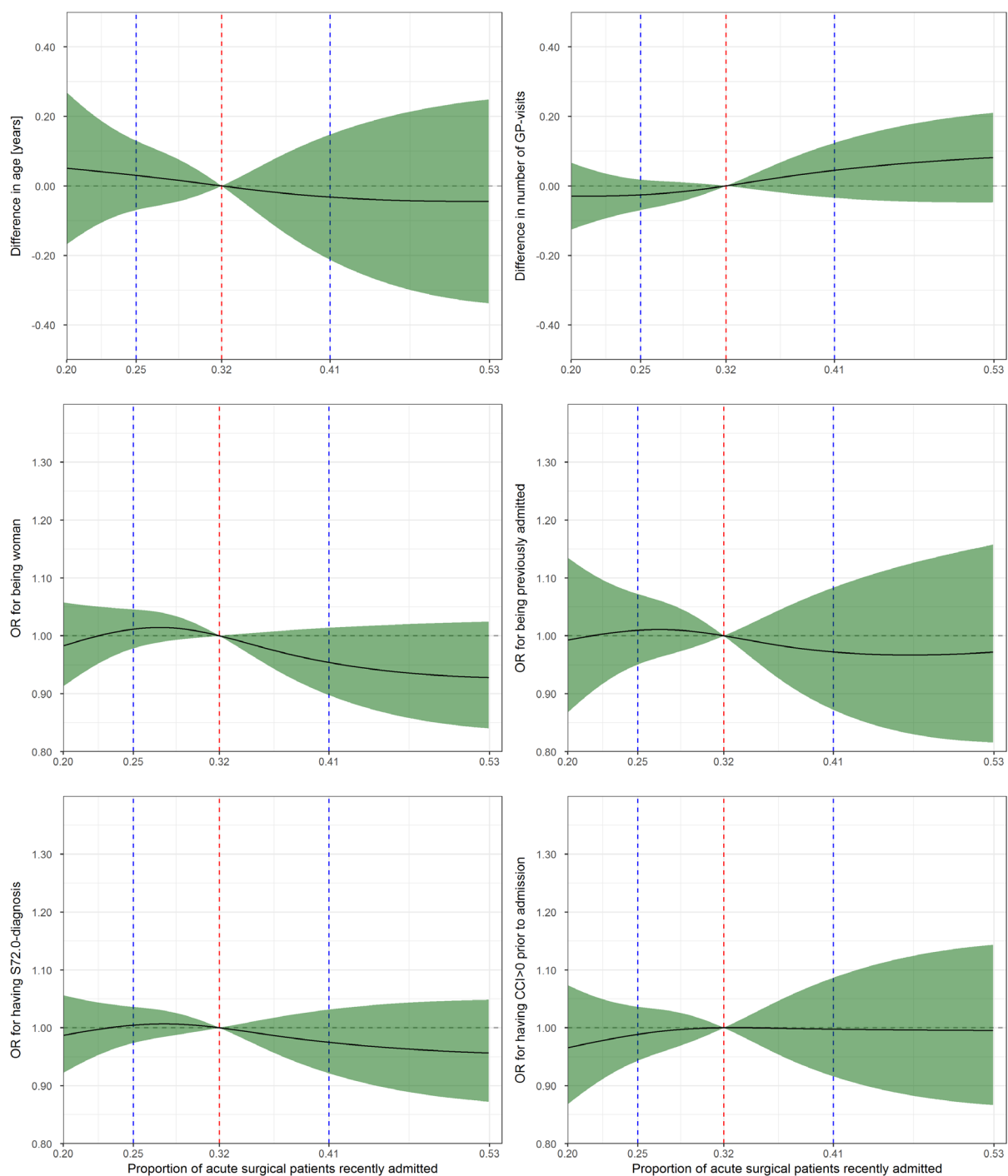
Figure e. Test of independence assumption. Association between indicators of patient condition (age, GP visits last 60 days, sex, being admitted within the previous 60 days, S72.0-diagnosis, and Charlson Comorbidity Index (CCI) > 0 on admissions one year prior) and the proportion of recently admitted surgical patients, with 95% confidence interval. The associations were computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner (GP) visits. The number of patients in these analyses was 65,097. OR, odds ratio.
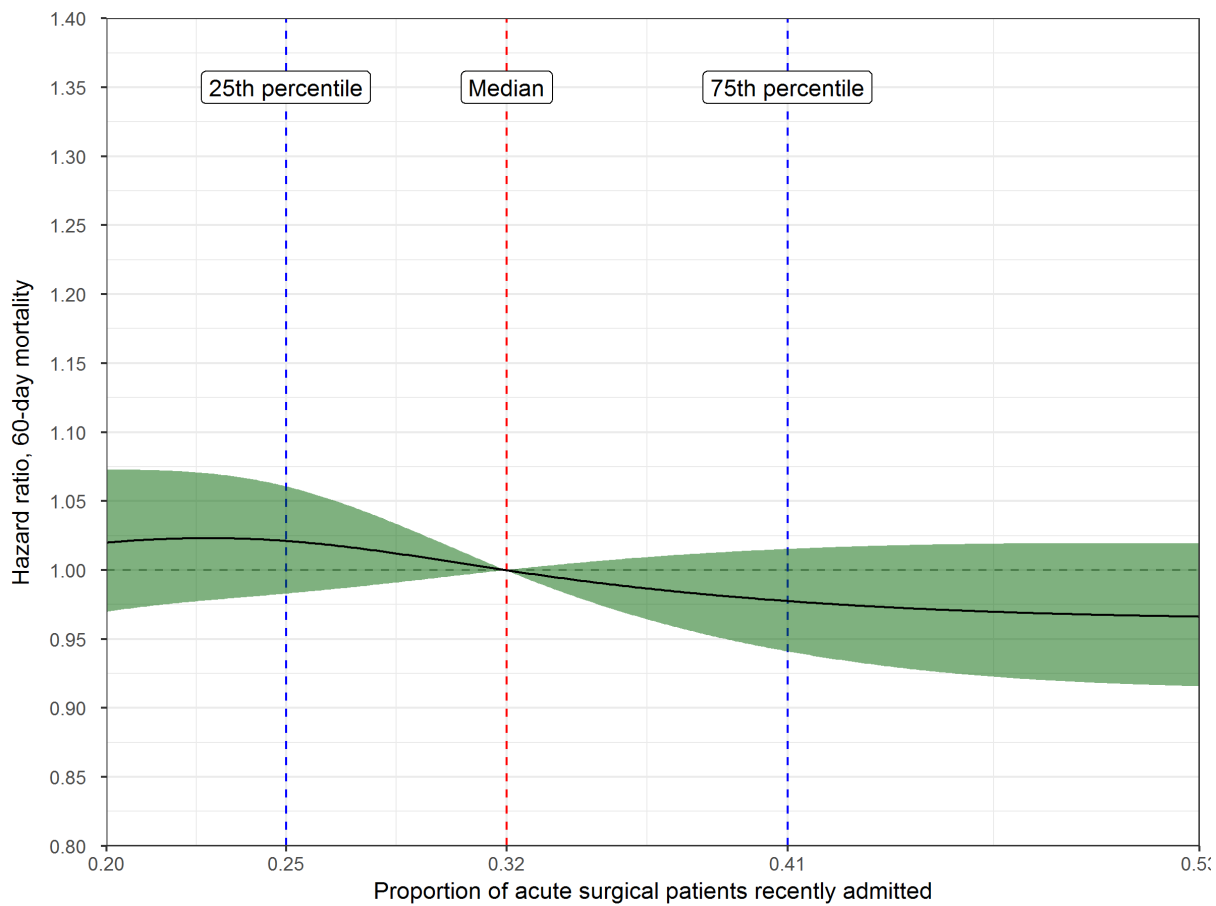
Figure f. Association between the proportion of recently admitted surgical patients and 60-day mortality for patients acutely admitted for pneumonia. Analysis of patients with pneumonia as main diagnosis (International Classification of Diseases of the World Health Organization (ICD)-10 J15.xx), aged 70 and over. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. The number of patients in these analyses was 88,660.
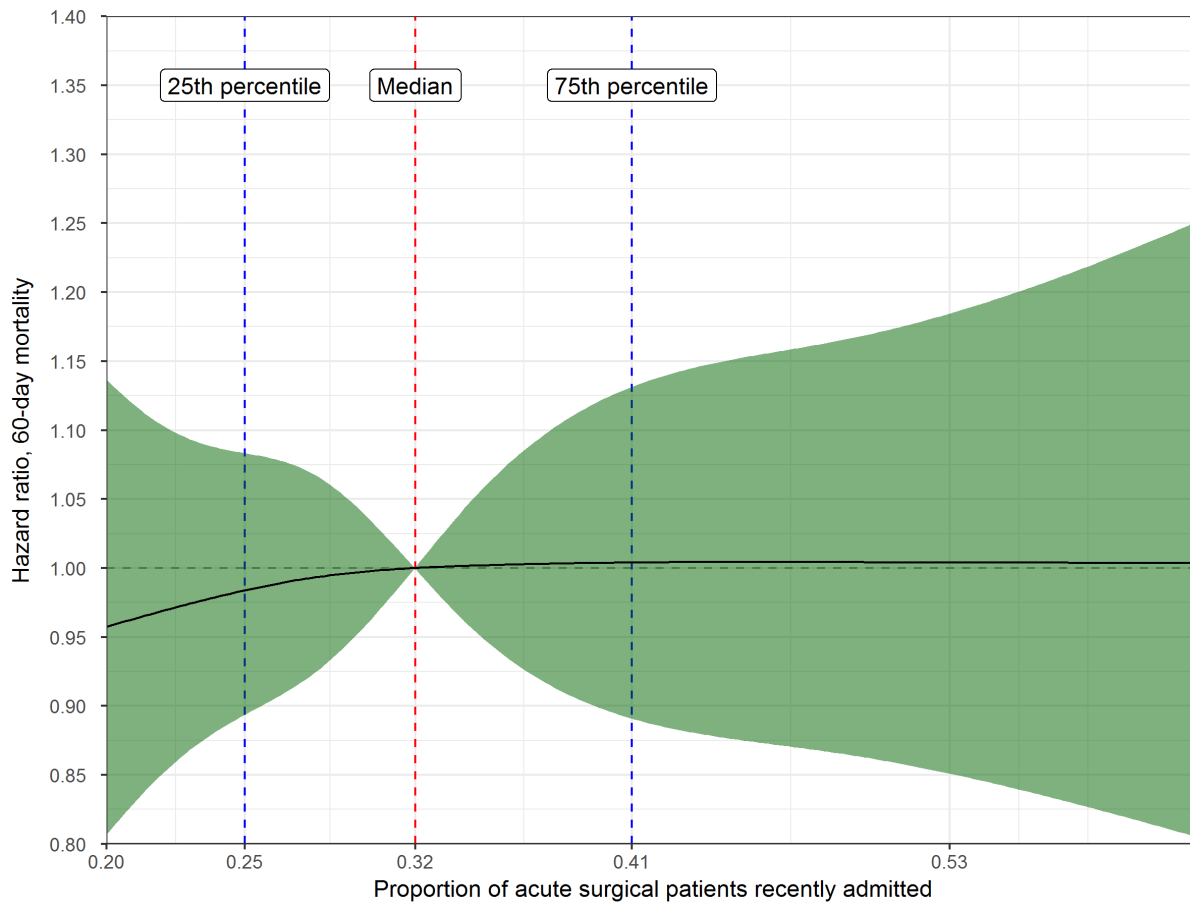
Figure g. Association between the proportion of recently admitted surgical patients and 60-day mortality for patients with cardiovascular disease. Analysis of acutely admitted patients who had surgery and main diagnosis from Chapter I in International Classification of Diseases of the World Health Organization (ICD)-10. The association was computed by comparing patients admitted at the same hospital, during the same month, on similar weekdays and times of the day, and were adjusted for age with a quadratic term, sex, S72.0-diagnosis, previous admission, and previous general practitioner visits. The number of patients in these analyses was 56,555.