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Obesity and outcomes in patients hospitalized with pneumonia

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Abstract

Studies suggest obesity is paradoxically associated with better outcomes for patients with pneumonia. Therefore, we examined the impact of obesity on short-term mortality in patients hospitalized with pneumonia. For 2 years clinical and radiographic data were prospectively collected on all consecutive adults admitted with pneumonia to six hospitals in Edmonton, Alberta, Canada. We identified 907 patients who also had body mass index (BMI, kg/m^2) collected and categorized them as underweight (BMI < 18.5), normal (18.5 to <25), overweight (25 to <30) and obese (>30). Overall, 65% were >65 years, 52% were female, and 15% reported recent weight loss. Eighty-four (9%) were underweight, 358 (39%) normal, 228 (25%) overweight, and 237 (26%) obese. Two-thirds had severe pneumonia (63% PSI Class IV/V) and 79 (9%) patients died. In-hospital mortality was greatest among those that were underweight (12 [14%]) compared with normal (36 [10%]), overweight (21 [9%]) or obese (10 [4%], p <0.001 for trend). Compared with those of normal weight, obese patients had significantly lower rates of in-hospital mortality in multivariable logistic regression analyses: adjusted odds ratio (OR), 0.46; 95% CI, 0.22–0.97; p 0.04. However, compared with patients with normal weight, neither underweight (adjusted OR, 1.13; 95% CI, 0.54–2.4; p 0.7) nor overweight (adjusted OR, 0.94; 95% CI, 0.52–1.69; p 0.8) were associated with in-hospital mortality. In conclusion, in patients hospitalized with pneumonia, obesity was independently associated with lower short-term mortality, while neither being underweight nor overweight were. This suggests a protective influence of BMIs > 30 kg/m^2 that requires better mechanistic understanding.

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Transparency Declaration

None of the authors have any conflicts of interest to disclose.

Contributions

SRM had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the analysis and will act as the guarantor. All authors participated in study conception, design, interpretation and critical revisions, and approved the final manuscript. SK wrote the initial draft. JKMS and DTE undertook analyses. SRM, DTE, TJM obtained funding and supervised the study. All authors have seen and approved the final version.

Keywords

Body mass index; community-acquired pneumonia; mortality; obesity; outcomes

Introduction

Obesity is associated with increased co-morbidity (e.g. diabetes, hypertension, sleep apnoea) and higher mortality directly proportional to increases in body mass index (BMI) [1–3]. Obesity is also independently associated with an increased risk of *acquiring* infections such as community-acquired pneumonia (CAP) [4,5]. Furthermore, obesity could lead to worse outcomes in those who develop infections, perhaps as a result of dysregulation of the inflammatory cascade involving increased levels of cytokines, adiponectin and leptin and exaggerated macrovascular and microvascular responses [4,6]. Obesity also leads to impairments in lung function that include adverse changes in mechanics and airway resistance and impaired gas exchange [7,8]. Last, the accumulation of obesity-related co-morbidities might lead to increased pneumonia-related mortality [8].

Conversely, low weight, especially if associated with malnutrition, may also be a risk factor for acquiring infections such as pneumonia and having poorer infection-related outcomes [8–13]. Unlike the case for obesity, the underlying aetiology of the weight loss (e.g. malignancy, substance use, cardiopulmonary cachexia) is often thought to be the mechanism underlying increased mortality and poorer pneumonia-related outcomes [1,8].

Given that obesity is associated with both an increased risk of developing pneumonia and an increased risk of total mortality, it could be assumed that obese individuals would have worse pneumonia-related outcomes. However, a few studies indicate that obesity may have a protective effect against pneumonia-related mortality [12,14,15]. This so-called ‘obesity paradox’ is poorly understood for acute infections, and therefore we examined the relationship between increased BMI and pneumonia-related mortality. We hypothesized that compared with normal weight, obesity would be associated with decreased in-hospital mortality.

Methods

Setting and Subjects

From 2000–2002, data were collected on a prospective cohort of 3415 people (>17 years) with community-acquired pneumonia who were admitted to six hospitals in Edmonton (population ~ 1 million), Alberta, Canada, and managed according to a clinical pathway. Detailed descriptions of the cohort and data collection methods have been previously published [16,17]. To enter the cohort, subjects had to have signs and symptoms of pneumonia (defined as ≥2 of the following: cough, pleurisy, shortness of breath, temperature >38°C, crackles, or bronchial breathing on auscultation) and a chest radiograph interpreted by the treating physicians as consistent with pneumonia. All patients were cared for according to a validated clinical pathway that had triage and site-of-care suggestions based on the Pneumonia Severity Index (PSI) and recommendations for investigations and antibiotic treatments. Patients with tuberculosis, cystic fibrosis, immuno-compromised status (e.g. chronic prednisone or other immunosuppressing agents) or frank aspiration, those who were pregnant or breast-feeding and those who required a direct admission to intensive care unit (ICU) were excluded. The study was exempted from the informed consent requirement and approved by the Health Research Ethics Board at the University of Alberta (Edmonton, Alberta, Canada).

Measurements

Data collected included patient sociodemographics (age, sex, residence), clinical characteristics (vital signs, co-morbidities, laboratory values), functional status, prescription drug use, vaccination history, and the official chest radiograph report as interpreted by a board-certified radiologist (vs. the interpretation of pneumonia made by the treating physicians). We categorized patients according to Systemic Inflammatory Response Syndrome (SIRS) criteria [18] and stress hyperglycaemia at admission (plasma glucose >6.1 mM (>110 mg/dL)) [19]. Functional status in the 2 weeks before admission was determined by patient or proxy interview and classified as completely independent ambulation or impaired. The Pneumonia Severity Index (PSI), a validated tool for predicting short-term mortality in patients with pneumonia, was used to assess disease severity [16,20].

Independent variable of interest

The study cohort included all individuals with pneumonia who had a BMI measured at the time of admission to hospital. Unlike the data prospectively collected for the study described earlier (e.g. the PSI, chest radiographs), height and weight were not mandated items. Thus, BMI was only captured if available in the patients' medical chart as part of routine hospital care and was recorded in about one-third of cases (see Results and Appendices 1–3). Patients were categorized according to the conventional World Health Organization (WHO) and National Institutes of Health (NIH) BMI classification: <18.5 kg/m^2 (underweight), 18.5 to <25 kg/m^2 (normal), 25 to 30 kg/m^2 (overweight), >30 kg/m^2 (obese) [21]. Related to BMI, we also collected information with respect to weight loss, defined as a self- or proxy-reported loss of weight of ≥ 5% over the preceding 1 year.

Outcomes

The primary outcome was all-cause in-hospital mortality. Secondary endpoints included the need for transfer to the ICU and 30-day all-cause readmission to hospital. For endpoints that took place after hospital discharge, we linked our cohort to routinely updated and previously validated administrative healthcare databases using unique but anonymized identifiers [16].

Analysis

We first plotted BMI against mortality using lowess plots. Using multivariable logistical regression, we evaluated the independent association between admission BMI and in-hospital mortality. Individuals with a normal BMI of 18.5–25 kg/m^2 served as the reference group. We did not attempt to impute missing values for BMI [22]. Unadjusted and adjusted odds ratios (aORs) and 95% confidence intervals (95% CIs) were calculated. We only forced pneumonia severity according to PSI class and BMI as an ordinal variable into each model. We then considered variables for inclusion in models if univariate associations with in-hospital mortality were $p < 0.1$ or if the variable was maldistributed across BMI categories or the variable confounded (>10% change in beta coefficient) the association between BMI and mortality. The final multivariable model included age, functional status, prior pneumococcal vaccination, chest radiograph confirmation, PSI and BMI. Hereafter, we refer to this as our fully adjusted model. We used the c-statistic (area under the curve) and the Hosmer-Lemeshow goodness of fit test to evaluate our final models.

We then replicated the analysis for in-hospital mortality after excluding those patients with clinically diagnosed pneumonia who eventually had an admission chest radiograph reported as normal. Although chest radiograph abnormalities are conventionally used to confirm the diagnosis of pneumonia, patients presenting with serious lower respiratory tract symptoms and signs are often 'clinically' diagnosed with pneumonia, admitted, and treated as such [23].

Finally, we carried out several sensitivity analyses. First, we examined the impact of self-reported weight loss on the outcome of in-hospital mortality. Second, we redid the analyses of in-hospital mortality after excluding patients from nursing homes, as the current definition of 'community-acquired' does not include nursing home-acquired pneumonia. Last, we repeated our analytical approach for two non-fatal endpoints: transfer to intensive care unit (ICU) and 30-day hospital readmission rates among those discharged home. All analyses were carried out using SAS version 9.2 (SAS Institute Inc., Cary, NC, USA).

Results

General characteristics

Of 3415 patients admitted to hospital with pneumonia, 907 (27%) had a BMI measured at admission. There were few clinically important or statistically significant differences between those who had BMI measured and those where it was missing (Appendix 1). The mean age was 68 years (SD = 17), 48% were female and 17% were from nursing homes. Nearly two-thirds of patients (63%) presented with severe pneumonia (Pneumonia Severity Index class IVor V); 79% had two or more SIRS criteria and 64% had stress hyperglycaemia at admission.

BMI and weight

The mean weight for the entire cohort was 73 kg (SD = 23) and the mean BMI was 27 (SD = 8). There were 84 (9%), 358 (39%), 228 (25%) and 237 (26%) individuals in the underweight, normal weight, overweight and obese categories, respectively. (As an aside, in the Edmonton health region, it has been estimated that 34% of adults are overweight and 18% obese [24].) Of note, fully 15% of patients reported recent weight loss. Characteristics of patients stratified by BMI category are presented in Table 1. Compared with normal weight patients (reference group), the underweight patients were more likely to be older, female and nursing home residents, more likely to report recent weight loss, and had more severe pneumonia. Conversely, when compared with normal weight patients, the obese patients were more likely to have diabetes and more likely to present with shortness of breath and tachycardia, but otherwise they had less severe pneumonia (Table 1).

In-hospital mortality in the overall cohort

Overall, 79 (9%) patients died in hospital. A curvilinear trend with higher rates of unadjusted mortality in the underweight group and much lower unadjusted mortality rates in the obese group was observed (Fig. 1). Specifically, there were 12 (14%) deaths in the underweight, 36 (10%) in the normal weight, 21 (9%) in the overweight and 10 (4%) in the obese category. Table 2 displays those variables significantly associated with in-hospital mortality in univariable analyses. In unadjusted analysis, obesity was associated with a significantly lower risk of mortality compared with the normal weight category (4% vs. 10% mortality for normal weight; unadjusted OR, 0.39; 95% CI, 0.19–0.81; p 0.01; Table 3). In fully adjusted models, obesity was still independently associated with a significantly lower rate of in-hospital mortality compared with normal weight (adjusted OR, 0.46; 95% CI, 0.22–0.97; p 0.04). However, mortality rates in the underweight (adjusted OR, 1.13; 95% CI, 0.54–2.4; p 0.7) and overweight groups (adjusted OR, 0.94; 95% CI, 0.52–1.69; p 0.8) were not significantly different compared with normal BMI (Table 3). The adjusted model for in-hospital mortality performed well according to the c-statistic (0.78, p <0.001) and goodness-of-fit tests (p 0.92).

In-hospital mortality in those with abnormal chest radio-graphs

When analyses were restricted to the 680 patients with chest-radiograph confirmed pneumonia, the findings were even more striking: there were 12 (17%) in-hospital deaths in the underweight, 30 (11%) in the normal weight, 19 (11%) in the overweight and 6 (4%) in the obese category. Even though the sample size was reduced by 227 patients, the independent association between obesity and in-hospital mortality became larger and more significant: adjusted OR, 0.31; 95% CI, 0.12–0.78; p 0.01 (Table 4). The adjusted model for in-hospital mortality in this subgroup analysis performed well according to the c-statistic (0.79, p <0.001) and goodness-of-fit tests (p 0.87).

Sensitivity analyses

First, inclusion of self-reported weight loss into the multivariable models did not alter the relationship observed between obesity and in-hospital mortality (adjusted OR, 0.47; 95% CI, 0.22–0.99; p 0.05); in addition, the interaction term between weight loss and BMI was not significant (p 0.17).

Second, after excluding 150 nursing home patients from analyses, the association between obesity and in-hospital mortality became even stronger and remained statistically significant (adjusted OR, 0.25; 95% CI, 0.10–0.63; p 0.004).

Third, there were 179 (20%) ICU transfers and 65 (7%) re-hospitalizations within 30 days. Compared with normal weight, there was no independent association between obesity and ICU transfer (adjusted OR, 0.78; 95% CI, 0.50–1.21; p 0.3) or 30-day readmission rates (adjusted OR, 0.81; 95% CI, 0.41–1.61; p 0.6 and Table 4). The same pattern held true when non-fatal endpoints were examined in analyses restricted to patients with abnormal chest radiographs (Table 5).

Discussion

In a cohort of almost 1000 patients hospitalized for community-acquired pneumonia, obese individuals had a significantly lower adjusted mortality rate compared with normal weight patients. This association was relatively strong (56% relative reduction in mortality) and robust in sensitivity analyses. Conversely, although underweight patients had the highest unadjusted mortality, after accounting for recent weight loss and severity of disease, this was not statistically significant.

Our results are broadly consistent with other research. In studies of chronic diseases such as coronary artery disease, heart failure and end-stage renal disease, several studies have demonstrated the obesity paradox [25–28]. The data for acute infections such as pneumonia are sparse and less consistent. In a study of 317 patients Corrales Medina *et al.* [15] reported a 12% relative reduction (adjusted OR, 0.88; 95% CI, 0.81–0.96; p <0.01) in pneumonia-related mortality per unit of BMI although they did not present data according to BMI category. Inoue *et al.* [14] found BMI >25 kg/m^2 to be associated with reduced mortality from pneumonia (HR, 0.70; 95% CI, 0.50–0.80; p <0.001) in a cohort of over 100 000 Japanese residents. In a study of 2600 men Lacroix *et al.* [12] demonstrated an inverse relationship between BMI quartiles and pneumonia-related mortality similar to what we observed. The few studies that have examined pneumonia have been limited by their lack of clinical data or their lack of information with respect to recent weight loss or the fact that their data were drawn from atypical populations [12–15].

If our findings are not the result of chance, what might explain our results? Obese individuals may have less physiological reserve [6] and present to hospital with less severe pneumonia. Our data show lower PSI scores and fewer radiographically confirmed

pneumonias in obese individuals, although all of our analyses were adjusted for these variables. Alternately (or additionally), the threshold for admitting an obese patient may be lower and this would yield spuriously lower mortality rates [26]. In our study, this is not likely as diabetes mellitus was the only maldistributed co-morbidity, and obese individuals were on more medications compared with the reference group. Last, higher BMI may directly lead to better outcomes and lower pneumonia-related mortality [12,14,15].

Why might obese patients with pneumonia have a survival advantage? First, obese patients may have increased nutritional reserves, which may help mitigate metabolic and inflammatory stress [8]. Second, some authors have suggested that 'casting' of the thoracic cavity (i.e. 'strapping' due to relatively increased chest wall adiposity) can reduce mechanical lung injury in the setting of pneumonia and other conditions by reducing transpulmonary pressure-mediated lung damage [29]. Third, although obesity is associated with impaired inflammation in general [4], it is also true that leptin production is increased in obesity and leptin enhances CD4 lymphocyte response towards T helper type 1 cells [8]. Clearly, much work remains to be done to elucidate the potential mechanism for protection related to obesity, especially in the setting of acute infections.

Several limitations of this study should be considered. First, only 27% of the cohort had BMI measured and documented and we have no information regarding the reasons for (or for not) documenting weight; in general, it is part of routine care. In comparing the characteristics of individuals with missing and available data (Appendix 1), few statistically significant and no clinically important differences were noted. Second, we could not distinguish between lean and adipose tissue or central and peripheral obesity, and we had no direct measure of nutritional reserves. Third, it is possible that the obese patients in our cohort, admitted to hospital with a clinical diagnosis of pneumonia, did not in fact have pneumonia but instead had less serious respiratory tract infections such as acute bronchitis or were misdiagnosed with pneumonia but had shortness of breath or fever for other reasons. Although chest radiographs are an imperfect reference standard for pneumonia [23], our results were unaltered when we restricted analyses to patients with abnormal chest radiographs demonstrating pulmonary infiltrates.

In conclusion, our study suggests that obese individuals with pneumonia are at significantly and substantially lower risk of mortality than normal weight individuals. Our study adds importantly to the reverse epidemiology literature and we believe it justifies the need to undertake more fundamental and mechanistic work to better understand the reasons for the obesity paradox in pneumonia.

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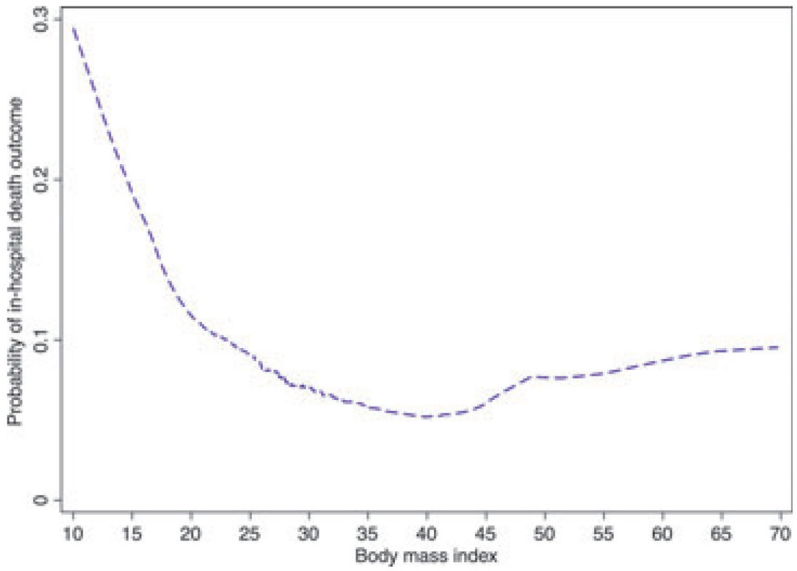

FIG. 1.
Rates of in-hospital pneumonia-related mortality according to body mass index.

TABLE 1

Characteristics of 907 patients admitted to hospital with pneumonia

	BMI categories				
Characteristics	**<18.5**	**18.5–25**	**25–30**	**>30**	**p-value**
N (%)	84 (9)	358 (39)	228 (25)	237 (26)	
Weight, kg ± SD	43 ± 7	61 ± 10	76 ± 9	99 ± 24	<0.001
Age, mean ± SD, years	73 ± 16	69 ± 19	69 ± 16	65 ± 16	0.007
Female sex, *n* (%)	58 (69)	161 (45)	91 (40)	121 (51)	<0.001
Non-smoker, *n* (%)	56 (67)	261 (73)	168 (74)	167 (70)	0.6
Impaired function, *n* (%)	19 (23)	41 (11)	23 (10)	18 (8)	0.002
Advanced directive, *n* (%)	17 (20)	45 (13)	14 (6)	13 (6)	<0.001
Nursing home, *n* (%)	23 (27)	64 (18)	35 (15)	28 (12)	0.009
>5% weight loss, *n* (%)	41 (49)	62 (17)	16 (7)	17 (7)	<0.001
Co-morbidities, *n* (%)					
Cardiovascular	41 (49)	171 (48)	119 (52)	125(53)	0.6
COPD	37 (44)	117 (33)	66 (29)	79 (33)	0.1
Diabetes mellitus	2 (2)	13 (4)	12 (5)	24 (10)	0.004
Known cancer	14 (17)	50 (14)	32 (14)	21 (9)	0.2
Chronic kidney disease	9 (11)	55 (15)	40 (18)	30 (13)	0.3
>5 medications, *n* (%)	9 (11)	49 (14)	44 (19)	53 (22)	0.01
Statins, *n* (%)	1 (1)	30 (8)	29 (13)	31 (13)	0.006
Pneumovax, *n* (%)	24 (29)	124 (35)	69 (30)	70 (30)	0.5
Flu vaccine, *n* (%)	19 (23)	109 (30)	61 (27)	53 (22)	0.1
Pneumonia symptoms, *n* (%)					
Fever	30 (36)	144 (40)	95 (42)	95 (40)	0.8
Cough	60 (71)	235 (66)	160 (70)	169 (71)	0.4
Sputum production	35 (42)	153 (43)	116 (51)	115 (49)	0.2
Shortness of breath	57 (68)	230 (64)	159 (70)	180 (76)	0.03
Pleuritic chest pain	5 (6)	34 (10)	38 (12)	26 (11)	0.4
Altered mental status	20 (24)	61 (17)	30 (13)	26 (11)	0.02
Pneumonia signs, *n* (%)					
Respirations >30 bpm	23 (28)	75 (22)	48 (22)	60 (27)	0.4

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Characteristics	BMI categories				p-value
	<18.5	18.5–25	25–30	>30	
Heart rate >100 bpm	43 (51)	166 (46)	91 (40)	124 (52)	0.05
Systolic pressure <90 mmHg	4 (5)	14 (4)	6 (3)	6 (3)	0.6
Crackles on auscultation	30 (36)	137 (38)	90 (39)	88 (37)	0.9
SIRS ≥2 criteria	70 (83)	271 (76)	176 (77)	199 (84)	0.06
Hyperglycaemia >6.1 mM	51 (61)	199 (56)	162 (71)	168 (71)	<0.001
Abnormal chest radiograph	70 (83)	280 (78)	169 (74)	161 (68)	0.009
Pneumonia severity index, *n* (%)					
Class I	2 (2)	5 (1)	2 (1)	7 (3)	0.004
Class II	5 (6)	49 (14)	36 (16)	57 (24)	
Class III	16 (19)	64 (18)	47 (21)	42 (18)	
Class IV	32 (38)	158 (44)	92 (40)	88 (37)	
Class V	29 (35)	82 (23)	51 (22)	43 (18)	
PSI score, mean ± SD	112 ± 34	106 ± 35	104 ± 34	97 ± 35	<0.001

TABLE 2

Characteristics of patients with pneumonia significantly associated with in-hospital mortality (univariable analysis)

Characteristics	Alive	In-hospital death	p-value
N (%)	828 (91)	79 (9)	
Body mass index categories, *n* (%)			
<18.5	72 (9)	12 (15)	0.02
18.5–25	322 (39)	36 (46)	
25–30	207 (25)	21 (27)	
> = 30	227 (27)	10 (13)	
Weight, kg ± SD	74 ± 23	68 ± 23	0.02
Age, mean ± SD, years	67 ± 17	77 ± 14	<0.001
Non-smoker, *n* (%)	585 (71)	67 (85)	0.008
Impaired function, *n* (%)	80 (10)	21 (27)	<0.001
Advanced directive, *n* (%)	753 (91)	65 (82)	0.01
Nursing home, *n* (%)	131 (16)	19 (24)	0.06
>5% weight loss, *n* (%)	117 (14)	19 (24)	0.02
Co-morbidities *n* (%)			
Cardiovascular	401 (48)	55 (70)	<0.001
Known cancer	101 (12)	16 (20)	0.04
Chronic kidney disease	117 (14)	17 (22)	0.08
Pneumovax, *n* (%)	270 (33)	17 (22)	0.04
Pneumonia symptoms, *n* (%)			
Fever	344 (42)	20 (25)	0.005
Cough	577 (70)	47 (59)	0.06
Sputum production	394 (48)	25 (32)	0.007
Pneumonia signs, *n* (%)			
Respirations >30 bpm	180 (23)	26 (35)	0.02
Systolic pressure <90 mmHg	24 (3)	6 (8)	0.03
Abnormal chest radiograph	613 (74)	67 (85)	0.03
Pneumonia severity index, *n* (%)			
Class I	16 (2)	0 (0)	<0.001
Class II	146 (18)	1 (1)	
Class III	165 (20)	4 (5)	
Class IV	336 (41)	34 (43)	
Class V	165 (20)	40 (51)	
PSI score, mean ± SD	101 ± 34	131 ± 30	<0.001

TABLE 3

Univariable and multivariable analysis for in-hospital mortality of 907 patients with pneumonia

	Unadjusted odds ratios	p-value	Adjusted* odds ratios	p-value
Body mass index categories				
<18.5	1.49 (0.74–3.00)	0.3	1.13 (0.54–2.39)	0.7
18.5–25 (reference)	1.00	–	1.00	–
25–30	0.91 (0.52–1.60)	0.7	0.94 (0.52–1.69)	0.8
> = 30	0.39 (0.19–0.81)	0.01	0.46 (0.22–0.97)	0.04
Age > 65 years	3.27 (1.74–6.14)	<0.001	2.33 (1.18–4.60)	0.02
Impaired function	3.39 (1.95–5.87)	<0.001	2.95 (1.64–5.30)	<0.001
Pneumovax	0.57 (0.33–0.99)	0.05	0.39 (0.22–0.70)	0.002
Abnormal chest radiograph	1.96 (1.04–3.69)	0.04	1.84 (0.95–3.55)	0.07
Pneumonia Severity Index Class IV/V	9.66 (3.86–24.2)	<0.001	7.11 (2.75–18.38)	<0.001

* c-statistic for model = 0.78, p <0.001; Hosmer-Lemeshow goodness-of-fit test, p 0.92.

TABLE 4

Fatal and non-fatal endpoints in 907 patients hospitalized with pneumonia, according to categories of body mass index

BMI categories (kg/m^2)	Death, n (%)	Adjusted * OR (95% CI)	p-value	Transfer to ICU, n (%)	Adjusted[a] OR (95% CI)	p-value	30-day readmission, n (%)	Adjusted[a] OR (95% CI)	p-value
<18.5	12 (14)	1.13 (0.54–2.39)	0.7	13 (15)	0.55 (0.28–1.09)	0.1	9 (11)	1.48 (0.66–3.33)	0.3
18.5–25	36 (10)	1.00	REF	79 (22)	1.00	REF	26 (7)	1.00	REF
25.1–30	21 (9)	0.94 (0.52–1.69)	0.8	45 (20)	0.88 (0.57–1.35)	0.6	16 (7)	0.98 (0.51–1.87)	0.9
>30	10 (4)	0.46 (0.22–0.97)	0.04	42 (18)	0.78 (0.50–1.21)	0.3	14 (6)	0.81 (0.41–1.61)	0.6

BMI, body mass index; ICU, intensive care unit; OR, odds ratio; REF, reference.

[a]Models adjusted for age, functional status, prior pneumococcal vaccination, chest radiograph confirmation and Pneumonia Severity Index.

TABLE 5

Fatal and non-fatal endpoints in 680 patients hospitalized with pneumonia and abnormal chest radiographs according to categories of body mass index

BMI categories (kg/m^2)	Death, n (%)	Adjusted * OR (95% CI)	p-value	Transfer to ICU, n (%)	Adjusted * OR (95% CI)	p-value	30-day readmission, n (%)	Adjusted * OR (95% CI)	p-value
<18.5	12 (17)	1.27 (0.58–2.81)	0.6	12 (17)	0.56 (0.27–1.16)	0.1	5 (7)	0.87 (0.31–2.45)	0.8
18.5–25	30 (11)	1.00	REF	66 (24)	1.00	REF	20 (7)	1.00	REF
25.1–30	19 (11)	0.98 (0.52–1.88)	0.9	40 (24)	0.93 (0.58–1.50)	0.8	10 (6)	0.80 (0.36–1.76)	0.6
>30	6 (4)	0.31 (0.12–0.78)	0.01	32 (20)	0.74 (0.45–1.23)	0.3	12 (7)	1.09 (0.52–2.31)	0.8

BMI, body mass index; ICU, intensive care unit; OR, odds ratio; REF, reference.

* Models adjusted for age, functional status, prior pneumococcal vaccination, chest radiograph confirmation and Pneumonia Severity Index.

Appendix 1

Comparison of the characteristics of patients with available vs. missing body mass index data.

Characteristic	Available data *N* = 907	Missing data *N* = 2508	p-value
Age, mean ± SD, years	68 ± 17	69 ± 18	0.37
Female, *n* (%)	476 (52)	1327 (53)	0.82
Non-smoker, *n* (%)	652 (72)	1914 (76)	0.008
Impaired function, *n* (%)	101 (11)	262 (10)	0.56
Advanced directive, *n* (%)	89 (10)	296 (12)	0.11
Nursing home, *n* (%)	150 (17)	487 (19)	0.06
Co-morbidities, *n* (%)			
Cardiovascular	456 (50)	1204 (48)	0.24
COPD	299 (33)	758 (30)	0.13
Diabetes mellitus	51 (6)	139 (6)	0.93
Known cancer	117 (13)	382 (15)	0.09
Chronic kidney disease	134 (15)	356 (14)	0.67
>5 medications, *n* (%)	155 (17)	395 (16)	0.35
Statins, *n* (%)	91 (10)	234 (9)	0.54
Pneumovax, *n* (%)	287 (32)	775 (31)	0.68
Flu vaccine, *n* (%)	242 (27)	663 (26)	0.89
SIRS >2, *n* (%)	716 (79)	2028 (81)	0.21
Hyperglycaemia >6.1, *n* (%)	580 (64)	1496 (60)	0.02
Respiratory rate >30, *n* (%)	206 (24)	584 (24)	0.85
Pneumonia severity index, *n* (%)			
Class I/II/III	332 (37)	955 (38)	0.43
Class IV/V	575 (63)	1553 (62)	
Abnormal chest radiograph, *n* (%)	680 (75)	1767 (70)	0.01

Appendix 2

Univariable and multivariable analysis of the need for intensive care unit transfer of 907 patients with pneumonia.

	Unadjusted odds ratio (95% CI)	p-value	Adjusted * odds ratio (95% CI)	p-value
BMI group				
<18.5	0.65 (0.34–1.23)	0.18	0.55 (0.28–1.09)	0.09
18.5–25	1.00	REF	1.00	REF
25–30	0.87 (0.58–1.31)	0.50	0.88 (0.57–1.35)	0.55
> = 30	0.76 (0.50–1.15)	0.20	0.78 (0.50–1.21)	0.26
Age > 65 years	0.40 (0.29–0.56)	<0.001	0.24 (0.16–0.36)	<0.001
Pneumonia Severity Index Class IV/V	1.81 (1.26–2.60)	0.002	3.34 (2.17–5.12)	<0.001
Impaired function	1.97 (1.24–3.12)	0.004	1.96 (1.20–3.20)	0.008
Abnormal chest radiograph	1.93 (1.26–2.97)	0.003	1.79 (1.14–2.81)	0.01

* c-statistic = 0.71, p <0.001; Hosmer-Lemeshow goodness-of-fit test, p 0.60.

Appendix 3

Univariable and multivariable analysis of the 30-day rates of readmission to hospital after surviving pneumonia and being discharged to the community.

	Unadjusted odds ratio (95% CI)	p-value	Adjusted * odds ratio (95% CI)	p-value
BMI group				
<18.5	1.53 (0.69–3.41)	0.29	1.48 (0.66–3.33)	0.34
18.5–25	1.00	REF	1.00	REF
25–30	0.96 (0.51–1.84)	0.91	0.98 (0.51–1.87)	0.95
> = 30	0.80 (0.41–1.57)	0.52	0.81 (0.41–1.61)	0.55
Age > 65 years	1.23 (0.71–2.13)	0.45	1.20 (0.65–2.22)	0.56
Pneumonia Severity Index Class IV/V	0.92 (0.55–1.54)	0.75	0.76 (0.43–1.35)	0.36
Impaired function	1.92 (0.99–3.72)	0.06	1.86 (0.94–3.66)	0.07
Pneumovax	1.38 (0.82–2.33)	0.54	1.34 (0.78–2.32)	0.27
Abnormal chest radiograph	0.86 (0.49–1.52)	0.61	0.84 (0.47–1.49)	0.54

* c-statistic = 0.68, p <0.001; Hosmer-Lemeshow goodness-of-fit test, p 0.68.