Preventive measures significantly reduced the risk of nosocomial infection in elderly inpatients during the COVID-19 pandemic

SHUANGSHUANG WU[1*], WEN LIU[1*], MINGJIONG ZHANG[1*], KAI WANG[1*], JIN LIU[2], YUJIA HU[3], QUAN SHE[1], MIN LI[1], SHAORAN SHEN[1], BO CHEN[1] and JIANQING WU[1]

[1]Jiangsu Provincial Key Laboratory of Geriatrics, Department of Geriatrics; [2]Clinical Research Institute, The First Affiliated Hospital of Nanjing Medical University, Nanjing, Jiangsu 210029, P.R. China; [3]Department of Business Analytics, Management School, Lancaster University, Lancaster, LA1 4YW, UK

Abstract. In December 2019, there was an outbreak of pneumonia of unknown causes in Wuhan, China. The etiological pathogen was identified to be a novel coronavirus, named severe acute respiratory syndrome coronavirus type 2 (SARS-CoV-2), which causes coronavirus disease 2019 (COVID-19). The number of infected patients has markedly increased since the 2019 outbreak and COVID-19 has also proven to be highly contagious. In particular, the elderly are among the group of patients who are the most susceptible to succumbing to COVID-19 within the general population. Cross-infection in the hospital is one important route of SARS-CoV-2 transmission, where elderly patients are more susceptible to nosocomial infections due to reduced immunity. Therefore, the present study was conducted to search for ways to improve the medical management workflow in geriatric departments to ultimately reduce the risk of nosocomial infection in elderly inpatients. The present observational retrospective cohort study analysed elderly patients who were hospitalised in the Geriatric Department of the First Affiliated Hospital with Nanjing Medical University (Nanjing, China). A total of 4,066 elderly patients, who were admitted between January and March in 2019 and 2020 and then hospitalised for >48 h were selected. Among them, 3,073 (75.58%) patients hospitalised from January 2019 to March 2019 were allocated into the non-intervention group, whereas the remaining 933 (24.42%) patients hospitalised from January 2020 to March 2020 after the COVID-19 outbreak were allocated into the intervention group. Following multivariate logistic regression analysis, the risk of nosocomial infections was found to be lower in the intervention group compared with that in the non-intervention group. After age stratification and adjustment for sex, chronic disease, presence of malignant tumour and trauma, both inverse probability treatment weighting and standardised mortality ratio revealed a lower risk of nosocomial infections in the intervention group compared with that in the non-intervention group. To rule out interference caused by changes in the community floating population and social environment during this 1-year study, 93 long-stay patients in stable condition were selected as a subgroup based on 4,066 patients. The so-called floating population refers to patients who have been in hospital for <2 years. Patients aged ≥65 years were included in the geriatrics program. The incidence of nosocomial infections during the epidemic prevention and control period (24 January 2020 to 24 March 2020) and the previous period of hospitalisation (24 January 2019 to 24 March 2019) was also analysed. In the subgroup analysis, a multivariate analysis was also performed on 93 elderly patients who experienced long-term hospitalisation. The risk of nosocomial and pulmonary infections was found to be lower in the intervention group compared with that in the non-intervention group. During the pandemic, the geriatric department took active preventative measures. However, whether these measures can be normalised to reduce the risk of nosocomial infections among elderly inpatients remain unclear. In addition, the present study found that the use of an indwelling gastric tube is an independent risk factor of nosocomial pulmonary infection in elderly inpatients. However, nutritional interventions are indispensable for the long-term wellbeing of patients, especially for those with dysphagia in whom an indwelling gastric tube is the most viable method of providing enteral nutrition. To conclude, the present retrospective analysis of the selected cases showed that enacting preventative and control measures resulted in the effective control of the incidence of nosocomial infections.

Correspondence to: Professor Jianqing Wu, Jiangsu Provincial Key Laboratory of Geriatrics, Department of Geriatrics, The First Affiliated Hospital of Nanjing Medical University, 300 Guangzhou Road, Nanjing, Jiangsu 210029, P.R. China
E-mail: jwunjmu@163.com

*Contributed equally

Introduction

In December 2019, a cluster of pneumonia cases of an unknown cause was reported in Wuhan, China. The pathogen causing

this condition was subsequently identified to be the novel coronavirus, named severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), with the pneumonia it causes named as coronavirus disease 2019 (COVID-19) (1). COVID-19 is highly infectious, such that the number of patients has increased sharply since its outbreak in 2019. COVID-19 has caused mortality and morbidity on an enormous scale, directly affecting societies across the world (2-8). Although the entire general population is considered to be susceptible to this disease, the elderly are among those who are the most vulnerable to succumbing to COVID-19 (9-11). Cross-infection in hospitals is one of the key routes of COVID-19 transmission (12), where elderly patients subsequently become more susceptible to nosocomial infection because of low immunity (13,14). In February 2020, the Chinese Center for Disease Control and Prevention reported that the fatality rate of confirmed COVID-19 cases was 2.3% in the general population, 3.6% in individuals aged 60-69 years, 8.0% in those aged 70-79 years and 14.8% in those aged 80 years (2). Mortality among patients infected with COVID-19 occurred mainly in those aged >80 years with underlying diseases, such as hypertension, cardiovascular disease and diabetes (12,15). In addition, the susceptibility of elderly patients to nosocomial infection, especially to nosocomial pulmonary infection, is particularly evident during the COVID-19 pandemic (11).

Nosocomial infections are also called hospital-acquired infections and can be acquired during a patient's stay at the hospital, where the symptoms are manifested either during hospitalisation or after discharge. Nosocomial infections are of particular concern, since they increase the disease burden to add to the risk of high morbidity and mortality (16). According to a definition proposed by the United States Center for Disease Control and Prevention in 1988, a nosocomial infection is an infection acquired during hospital stay that did not exist or was at an incubation stage upon admission (17). Clinically, infections that occur 48 or 72 h after hospital admission are typically referred to as hospital-acquired infections (18). Given the deterioration of physical and immune functions and the development of primary diseases, elderly patients are at high risk of nosocomial infection with poor prognosis (18). Nosocomial infections in elderly inpatients lead to prolonged hospital stays and increased risk of more serious conditions, including sepsis, organ dysfunction and multi-organ dysfunction (19). Specifically, nosocomial pneumonia is the most common hospital-related infection that has high rates of morbidity and mortality in addition to high levels of healthcare resource consumption (20-24).

Nosocomial infections also pose serious challenge to healthcare professionals globally during the COVID-19 pandemic. Nosocomial infection of COVID-19 directly impacts the quality of life of patients and also results in extra expenditure to hospitals (12,25-27). Considering the high risk of human-to-human transmission of SARS-CoV-2 infection, the majority of hospitals, especially those in China, have established a series of systems to control nosocomial SARS-CoV-2 infection. During the COVID-19 pandemic, a series of special measures were developed for elderly inpatients seeking medical treatment and hospitalisation at the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University. As a result, no hospitalised patients or medical staff developed

SARS-CoV-2 infection and the incidence of nosocomial infections was significantly reduced. In the present study, measures used to control nosocomial infections in elderly patients during the COVID-19 pandemic were analysed. The objective was to compare the incidence of nosocomial infection in the previous routine medical setting with that following the implementation of epidemic prevention and control measures. These results show that epidemic prevention and control measures can improve the medical environment, in addition to reducing the burden and harm caused by nosocomial infection.

Patients and methods

Ethics. The present retrospective observational cohort study analysed elderly patients hospitalised in the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University (Nanjing, China). The institutional review board of The First Affiliated Hospital with Nanjing Medical University approved this study and granted a waiver of informed consent from study participants because of the retrospective design. In the present retrospective study, patient data were obtained through the electronic medical record system.

Data collection. A total of 4,066 elderly patients admitted from January to March in 2019 and 2020 who were hospitalised at The First Affiliated Hospital with Nanjing Medical University for >48 h were selected. The inclusion criteria were as follows: i) Patients aged ≥65 years; and ii) hospital stay >48 h. The exclusion criteria were as follows: i) Patients aged <65 years; ii) hospital stay ≤48 h. Among them, 3,073 (75.58%) patients hospitalised from January 2019 to March 2019 were designated into the non-intervention group, whereas the remaining 933 (24.42%) patients hospitalised from January 2020 to March 2020 after the COVID-19 outbreak were designated into the intervention group. To rule out any changes caused by the community floating population and the social environment during this 2-year study, 93 long-stay patients in stable condition were selected as a subgroup based on the 4,066 patients for longitudinal analysis. The community floating population refers to patients who have been hospitalised in the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University for <2 years. The age-adjusted Charlson Comorbidity Index (aCCI) is a more widely used comorbidity scoring system than CCI, which quantifies comorbidities based on the types and severity of a patients' diseases and can be used to predict the risk of death from a disease. The higher the aCCI score, the higher the risk of mortality. By contrast, the lower the aCCI score, the lower the risk (28-30).

Long-stay patients refer to those who have been hospitalised in the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University for ≥2 years. Because this group of patients include those with multiple chronic diseases, homes or nursing homes cannot stabilise their physical condition and they therefore require long-term hospitalisation. The patients in stable conditions do not include those in acute phases of the disease or those that suffer from malignancies. Patients aged >65 years were included into the geriatrics program. The incidence of nosocomial infections during the epidemic prevention and control period (24 January 2020 to 24 March 2020) and the previous period of hospitalisation

(24 January 2019 to 24 March 2019) was analysed. Of these 93 long-stay patients, 93 were all enrolled according to the inclusion criteria. The inclusion criteria were as follows: i) Patients aged ≥65 years; ii) hospital stay ≥2 years; and iii) patients in a stable condition. The exclusion criteria were as follows: i) Patients aged <65 years; ii) hospital stay <2 years; iii) patients in the acute phase of a disease; iv) patients with malignant tumours who were undergoing chemotherapy, radiotherapy, immunotherapy; or v) patients that had a terminal disease. The objective was to compare the incidence of nosocomial infection in the previous routine medical setting with that following the implementation of the epidemic prevention and control measures.

Interventions. On 24 January 2020, The First Affiliated Hospital with Nanjing Medical University officially launched its first-level response to the COVID-19 pandemic (31). Elderly patients in the geriatric department were mainly divided into the following groups: Inpatients; outpatients; discharged patients; and patients with chronic disease. These patients were followed up for personalised management according to their conditions.

During hospital visits, all patients were required to wear masks, following which their body temperatures were checked and epidemiological history was recorded. If any of the patients showed symptoms of fever and pneumonia, they were transferred to a special unit, namely the 'fever unit', which was designed to observe and isolate patients suspected of infection. For patients with suspected symptoms, novel coronavirus nucleic acid tests on oropharyngeal swabs, chest CT and blood tests, including routine blood test and C-reactive protein test, were performed in a negative-pressure isolation room (32,33). Novel coronavirus nucleic acid test was performed using reverse transcription-quantitative PCR (RT-qPCR). The clinical samples of patients with PCR-confirmed COVID-19 were obtained in the form of throat swabs. Different conserved SARS-CoV-2 gene sequences can be targeted for RT-qPCR detection. Proposals from previous reports suggest using RT-qPCR as the molecular assay for detecting SARS-CoV-2 (4,34). Throughout all processes, all medical staff must wear masks, isolation suits and wash their hands. A professional online service for assessment, diagnosis and treatment was also set up for the management of patients with chronic disease and follow-up of discharged patients to avoid unnecessary hospital visits, reduce the risk of nosocomial infections and burden of hospital outpatient service to facilitate the reasonable allocation of medical resources. A nosocomial infection is an infection acquired during hospital stay that did not previously occur or was at the incubation stage upon admission (17).

For pre-diagnosis, an outpatient waiting area was set up according to the 1-m social distance rule to avoid cross-infection in the hospital. Patients with mild illness were treated in a separate room both during the early outbreak (2019) and under the current management protocols (2020). In the outpatient geriatric department, due to the limited ability of self-care and communication difficulties displayed by the elderly patients, only one individual was allowed to accompany the patients into the consultation room. Doctors, patients and accompanying staff were all required to wear masks at all times.

For outpatients with chronic diseases, the prescription dosage was extended to 3 months depending on the condition. In situations where the drug was urgently required by the patients but could not be procured, solutions included temporary procurement, logistics and delivery, door-to-door delivery and other professional online services. In addition, to guarantee the pharmacological needs of the patients during the epidemic, patients who are in urgent need of drugs (anticoagulants, insulin, anti-rejection drugs for organ transplantation and emergency drugs for sudden diseases) can contact the nearest drug handling enterprises in their residential areas for consultation and purchase drugs in cases of drug shortages in hospitals.

Preventive management. The First Affiliated Hospital with Nanjing Medical University has successfully formulated seven editions of hospitalisation standards for inpatients, of which the seventh version is quoted here (35). At the beginning of the outbreak, patients who had to be admitted to hospital due to their condition required examination before admission. Chest CT, C-reactive protein estimation, blood routine test and novel coronavirus nucleic acid tests were performed before hospitalisation. Patients without epidemiological exposure to COVID-19 cases were admitted to the hospital within 14 days of examination. At the epidemic control stage, the hospital ward was arranged into single rooms, where temporary isolation wards were allocated for nucleic acid testing, chest CT and blood sample analysis before the patients were admitted. If the results of nucleic acid detection, chest CT and blood sample analysis, along with the epidemiological history assessment, were negative, hospital-acquired COVID-19 infection would be ruled out. It was necessary to conduct nucleic acid detection tests twice for high-risk patients, such as those with a recent history of fever and characteristic signs of COVID-19 according to CT images. Multiple patchy 'ground glass' opacities in the bilateral multiple lobular regions with periphery distribution are typical chest CT features of COVID-19 pneumonia, where interlobular thickening and adjacent pleura can also occur (36). If the nucleic acid test results were positive, the patient would then be immediately isolated and sent to the negative pressure isolation room through a special channel. In addition, any medical staff members exposed to a patient suspected of COVID-19 were isolated under observation for 14 days.

The principle of 'no companion for mild cases' and 'one companion for severe cases' was implemented in the geriatrics ward. The accompanying personnel was required to undergo a nucleic acid test before entering the ward. In addition, patients and caregivers were not allowed to enter or leave the ward unauthorised.

During the hospitalisation period, family members were not allowed to visit the patients. Therefore, the elderly inpatients were encouraged to communicate with their families through 'cloud visitation'. If the elderly inpatient did not know how to use the Internet for video chat, the nurses would provide assistance.

The COVID-19 outbreak has affected not only the lifestyle of elderly patients but also their mental health. Elderly patients, especially inpatients, tend to be more prone to depression, anxiety and insomnia (37,38). In particular, 10-15% elderly

patients suffer from clinical depression, which requires serious expert intervention (37,38). Behaviour driven by negative emotions not only aggravate the disease course but can also adversely affect ward management (39). Therefore, psychological protection for elderly patients forms an important part of the clinical treatment strategy (40,41). To address this, a 'mind comfort room' managed by clinical psychologists and medical staff was set up at the hospital. This 'mind comfort room' is a spacious apartment for elderly inpatients, where they can read magazines, watch movies, listen to music and play chess. In addition, sufficient space was provided for elderly inpatients to perform exercises, such as Tai chi and aerobic gymnastics.

Publicity and education on epidemic prevention were provided for the discharged patients. Follow-up telephone calls were made and online lectures on diseases were conducted regularly. Management procedures for both outpatients and inpatients are shown in Figs. 1 and 2, respectively.

Statistical analyses. All categorical data were described as frequency (N, %) and calculated with the Wilson score using the 95% confidence interval (CI). Comparisons were performed using the non-parametric Mann-Whitney or Kruskal-Wallis tests for two- and multiple-independent samples, respectively. Univariate and multivariate logistic regression models were used to compare clinical outcomes between the groups, where the association between the outcome and each variable/research factor, including age, sex, nervous system, respiratory system, endocrine system, digestive system, cardiovascular system, urinary system, ELSE, malignant tumor, trauma and nosocomial infection, were first analysed. Although these factors can be used as independent risk factors, there may be correlations among different factors, where part of this correlation among these factors can be masked within the univariate analysis. As a result, multivariate logistic regression was then used to detect the interactions of the correlation among these factors with the results.

Propensity score matching analysis was performed to mitigate the effect of selection bias and potential confounding factors between two groups. Propensity scores were calculated using all variables except for interventions, namely age, sex and underlying disease. For propensity score matching, a nearest-neighbour 1:2 matching scheme (42) with a calliper size of 0.1 was used. Inverse probability treatment weighting (IPTW) (43,44) and standardised mortality ratio weight (SMRW) (45-47) were calculated based on the logistic regression model and used to evaluate the risk of nosocomial infections. Results were stratified for age, which is known to be associated with variations in the incidence of nosocomial infections (11,13). By contrast, the generalised estimating equation (GEE) model (48) with a negative binomial distribution was generated using an unstructured working correlation matrix to investigate the risk of nosocomial infections. This utilises a related structure describing the different measured outcomes without any assumptions being made about its structure:

$$\mathrm{Corr}(Y_{ij}, Y_{ik}) = \{1 \qquad j = k \; a_{jk} \qquad j \neq k$$

In this case, Y_{ik} represents the kth response of the ith patient, whereas a_{jk} represents the correlation coefficient between the

j^{th} response and the kth response. In particular, Y_{ij} represents the outcome of the jth hospitalisation of the ith patient, whilst Y_{ik} represents the outcome of the kth hospitalisation of the ith patient. Infection is the specific outcome.

Specifically, model 0 represents the unadjusted base model, whereas model I, represents that adjusted for sex and age at baseline. Model II represents model I that was adjusted further for chronicity disease, malignant tumor and CCI. The variables included in the GEE model are similar to those included in logistic regression. Since the outcome variables were derived from a patient's multiple hospitalisations, the GEE models took into account the clustering of multiple hospitalisations of the same patient to minimise bias when producing estimates (49). Nomogram construction and validation were performed in accordance with a previously reported guideline (50). A nomogram was constructed according to the independent prognostic factors of survival. Based on the logistic, dichotomous and sequential screening analyses, a nomogram incorporating the risk factors was created for predicting infection outcomes using the EmpowerStats statistical software 2.0 (http://www.empowerstats.net/), which was calculated using the R packages 'Survival' and 'Rms' (R version 3.4.3) (51-53).

Comparisons among categorical variables were analysed by the χ2 test. All statistical tests were performed using SPSS 22.0 software (IBM Corp.) and the EmpowerStats statistical software 2.0 (www.empowerstats.com; X&Y Solutions Inc.). P<0.05 was considered to indicate a statistically significant difference.

Results

Baseline characteristics of the participants. Among the 4,066 patients, >50% were elderly aged >70 years, where 66.3% were male. The three dominant chronic diseases in the cohort were disorders in the nervous system (n=1,080, 26.56%), digestive system (n=941, 23.14%) and cardiovascular system (n=466, 11.46%). Parameters (age, sex, nervous system, respiratory system, endocrine system, digestive system, cardiovascular system, malignant tumor, trauma, and nosocomial infection) between the intervention and non-intervention groups were different except for urinary system (Table I). Specifically, there was a higher proportion of patients in the nervous system, respiratory system, digestive system, cardiovascular system, trauma and nosocomial infection categories in the unintervened group, whilst a higher proportion of patients was observed in the endocrine system and malignant tumor categories in the intervened group. The proportion of patients aged <70 years old was higher, whereas that of patients aged ≥70 years was lower, in the unintervened group compared with that in the intervened group. There was difference in the intervention and non-intervention groups at the sex ratios of the patients recruited in study setting with unweighted or propensity 1:2 matching, where patients included in the population analysis predominantly male. After adjusting for all covariates by Propensity score matching (PSM) analysis, a similar distribution in the different covariates was observed except for age, nervous system, digestive system, urinary system and malignant tumor. After the IPTW and SMRW adjustment, the association between intervening measures and nosocomial infection remained significant. However, none of
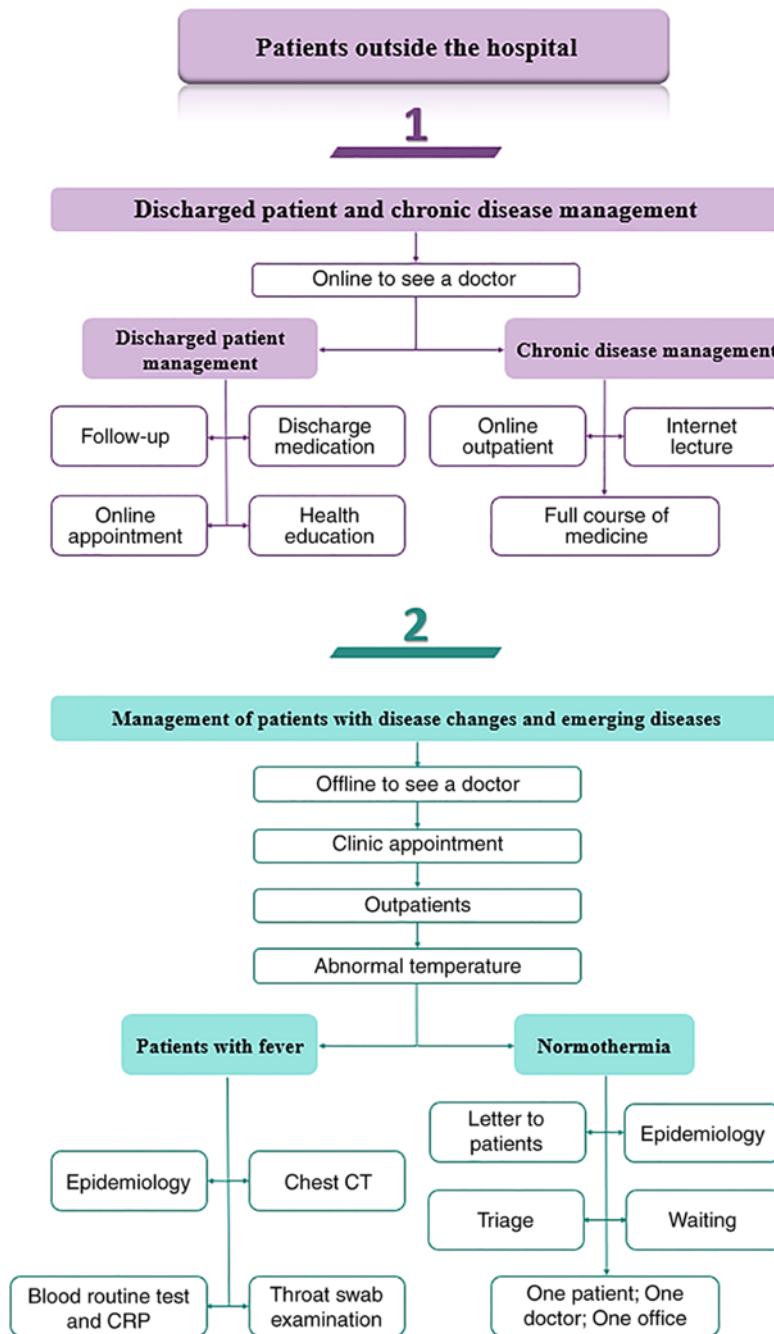
Figure 1. Management procedures for outpatients. CRP, C-reactive protein.

the other parameters had their significance preserved, although a difference was observed in age distribution after SMRW, which is similar to those after unadjusted analysis (Table I). Comprehensively, the nosocomial infection rate between the intervention and non-intervention groups was found to be significantly different regardless of the calculation methods used, where there was a lower proportion in the intervened group (non-intervention vs. intervention: Unweighted, 4.72 vs. 1.91%, P<0.001; propensity 1:2 matching, 4.94 vs. 1.73%, P<0.001; IPTW, 4.79 vs. 1.7%, P<0.001; SMRW, 5 vs. 1.91%, P<0.001).

Multivariate logistic regression and stratified analysis of interventions. In the multivariate logistic regression model, the risk of nosocomial infections was lower in the intervention group compared with that in the non-intervention group [odds ratio (OR)=0.36; 95% CI=0.22-0.59 and P<0.001; Table II]. Even after IPTW and SMRW adjustment, the differences remained significant (IPTW: OR=0.33; 95% CI=0.25-0.44 and P<0.001; SMRW: OR=0.35; 95% CI=0.21-0.61; P=0.002; Table II). Because it was found in previous clinical studies that nosocomial infection in the elderly is more common, age was considered to be a risk factor of nosocomial infection (11,13), it was necessary to stratify the analysis by age (aged 70-90 years: Unadjusted, OR=2.46; 95% CI=1.64-3.68 and P<0.001; IPTW, OR=2.35, 95% CI=1.71-3.24 and P<0.001; SMRW, OR=2.35, 95% CI=1.23-4.49 and P=0.0098; aged ≥90 years: Unadjusted, OR=3.39, 95% CI=2.14-5.39 and
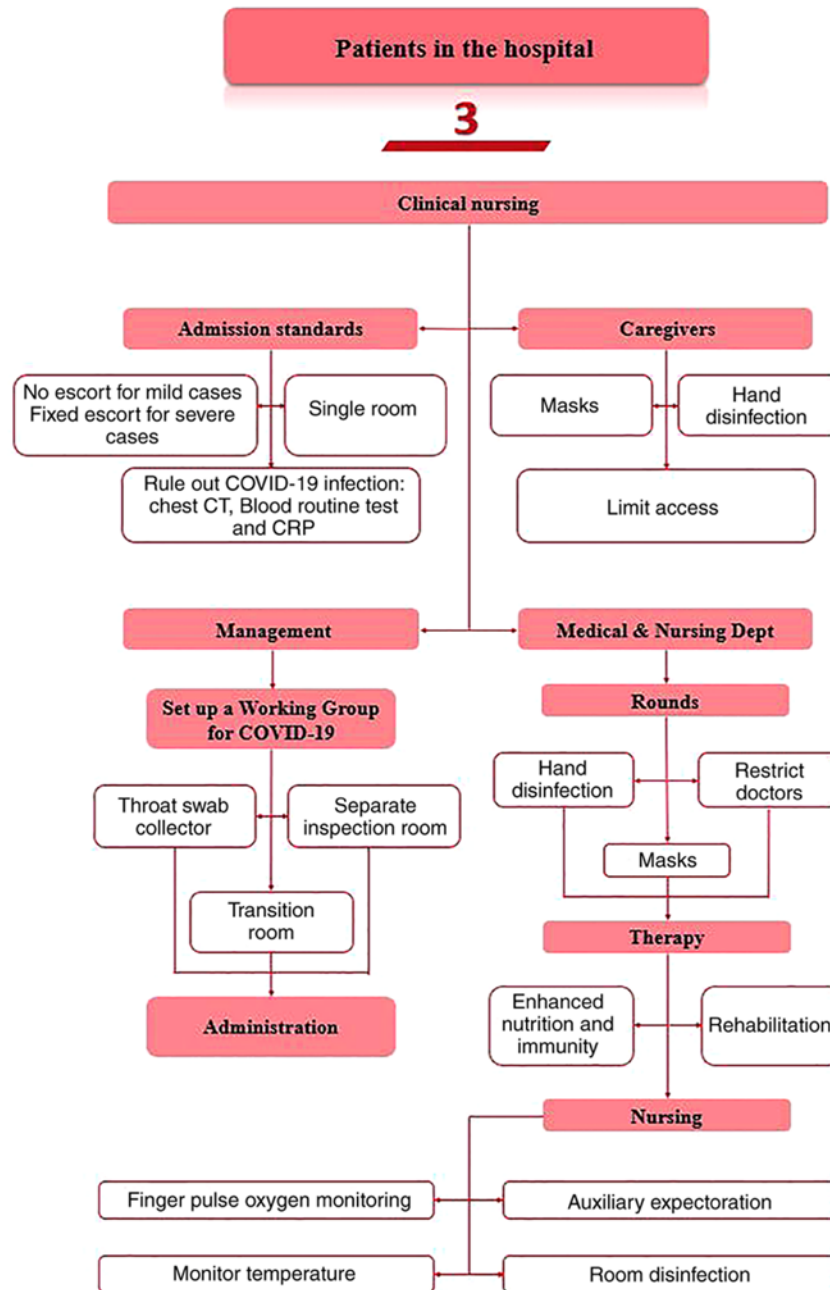
Figure 2. Management procedures for inpatients. CRP, C-reactive protein.

P<0.001; IPTW, OR=3.47, 95% CI=2.42-4.98 and P<0.001; SMRW, OR=3.34; 95% CI=1.61-6.96; P=0.0012; Table II). In addition, a stratified analysis of gastric catheterisation was performed to exclude this confounding factor. After the age stratification and adjustment for sex, chronic disease, malignant tumour and trauma, the results of both IPTW and SMRW showed a lower risk of nosocomial infection in the intervention group compared with that in the non-intervention group (aged <70 years: IPTW, OR=0.39; 95% CI=0.23-0.68 and P=0.0008; SMRW, OR=0.47; 95% CI=0.16-1.44 and P=0.1887; aged 70-90 years: IPTW, OR=0.28, 95% CI=0.18-0.44; P<0.001; SMRW, OR=0.34; 95% CI=0.15-0.76 and P=0.0091; age ≥90 years: IPTW, OR=0.28; 95% CI=0.17-0.46 and P<0.001; SMRW, OR=0.26; 95% CI=0.10-0.68 and P=0.0064; Table III).

Baseline characteristics of the long-stay subgroup population. To rule out any changes owing to the community floating population and social environment during the present 1-year study, 93 long-stay patients in stable conditions were selected as the study population for longitudinal analysis. Charlson comorbidity index (CCI) was included as a new variable, which is commonly used to assess the impact of co-comorbidities on patient survival over 10 years in addition to the underlying disease for which the patient is currently being treated (28-30). The age-adjusted CCI (aCCI) is a more widely used Comorbidity scoring system than CCI (28). It quantifies comorbidities based on the patients' age, types and severity of a patient's diseases and can be used to predict the risk of mortality from a disease (28-30). By contrast, the generalised estimating equation (GEE)

Table I. Baseline characteristics of the elderly patients in the present study.[a]

A, Unweighted sample (n=4,066)

Characteristics	Total [n=4,066; n (%)]	Unintervened [n=3,073; n (%)]	Intervened [n=993; n (%)]	P-value
Age, years				<0.001
<70	1,987 (48.87)	1,567 (50.99)	420 (42.30)	
70-90	1,404 (34.53)	1,040 (33.84)	364 (36.66)	
≥90	675 (16.60)	466 (15.16)	209 (21.05)	
Sex				0.005
Male	2,696 (66.31)	2,001 (65.12)	695 (69.99)	
Female	1,370 (33.69)	1,072 (34.88)	298 (30.01)	
Nervous system	1,080 (26.56)	857 (27.89)	223 (22.46)	<0.001
Respiratory system	329 (8.09)	280 (9.11)	49 (4.93)	<0.001
Endocrine system	393 (9.67)	224 (7.29)	169 (17.02)	<0.001
Digestive system	941 (23.14)	766 (24.93)	175 (17.62)	<0.001
Cardiovascular system	466 (11.46)	388 (12.63)	78 (7.85)	<0.001
Urinary system	141 (3.47)	107 (3.48)	34 (3.42)	0.931
ELSE	59 (1.45)	51 (1.66)	8 (0.81)	0.05
Malignant tumor	597 (14.68)	376 (12.24)	221 (22.26)	<0.001
Trauma	47 (1.16)	42 (1.37)	5 (0.50)	0.027
Nosocomial infection	164 (4.03)	145 (4.72)	19 (1.91)	<0.001

B, Propensity 1:2 matching (n=2,466)

Characteristics	Total [n=2,466; n (%)]	Unintervened [n=1,598; n (%)]	Intervened [n=868; n (%)]	P-value
Age, years				0.793
<70	1,094 (44.36)	702 (43.93)	392 (45.16)	
70-90	899 (36.46)	590 (36.92)	309 (35.60)	
≥90	473 (19.18)	306 (19.15)	167 (19.24)	
Sex				0.047
Male	1,656 (67.15)	1,051 (65.77)	605 (69.70)	
Female	810 (32.85)	547 (34.23)	263 (30.30)	
Nervous system	471 (19.10)	306 (19.15)	165 (19.01)	0.933
Respiratory system	181 (7.34)	136 (8.51)	45 (5.18)	0.002
Endocrine system	274 (11.11)	128 (8.01)	146 (16.82)	<0.001
Digestive system	492 (19.95)	322 (20.15)	170 (19.59)	0.737
Cardiovascular system	284 (11.52)	217 (13.58)	67 (7.72)	<0.001
Urinary system	127 (5.15)	95 (5.94)	32 (3.69)	0.015
ELSE	57 (2.31)	26 (1.63)	31 (3.57)	0.002
Malignant tumor	548 (22.22)	341 (21.34)	207 (23.85)	0.152
Trauma	32 (1.30)	27 (1.69)	5 (0.58)	0.02
Nosocomial infection	94 (3.81)	79 (4.94)	15 (1.73)	<0.001

C, IPTW (n=4,066)

Characteristics	Total [n=4,066; n (%)]	Unintervened [n=3,073; n (%)]	Intervened [n=993; n (%)]	P-value
Age, years				0.058
<70	1,987 (48.87)	1,510 (49.15)	477 (48.04)	
70-90	1,415 (34.80)	1,082 (35.2)	333 (33.53)	
≥90	664 (16.33)	481 (15.65)	183 (18.43)	
Sex				0.947
Male	2,694 (66.26)	2,037 (66.28)	657 (66.18)	
Female	1,372 (33.74)	1,036 (33.72)	336 (33.82)	

Table I. Continued.

C, IPTW (n=4,066)

Characteristics	Total [n=4,066; n (%)]	Unintervened [n=3,073; n (%)]	Intervened [n=993; n (%)]	P-value
Nervous system	1,069 (26.29)	814 (26.49)	255 (25.72)	0.578
Respiratory system	336 (8.26)	249 (8.11)	87 (8.8)	0.429
Endocrine system	387 (9.52)	293 (9.54)	94 (9.44)	0.909
Digestive system	943 (23.19)	711 (23.14)	232 (23.34)	0.875
Cardiovascular system	459 (11.29)	351 (11.43)	108 (10.83)	0.538
Urinary system	140 (3.44)	106 (3.46)	34 (3.41)	0.933
ELSE	58 (1.43)	44 (1.44)	14 (1.37)	0.848
Malignant tumor	609 (14.98)	457 (14.86)	152 (15.34)	0.669
Trauma	49 (1.21)	36 (1.16)	13 (1.33)	0.624
Nosocomial Infection	164 (4.03)	147 (4.79)	17 (1.7)	<0.0001

D, SMRW (n=4066)

Characteristics	Total [n=4,066; n (%)]	Unintervened [n=3,073; n (%)]	Intervened [n=993; n (%)]	P-value
Age, years				0.006
<70	1,755 (43.16)	1,335 (43.44)	420 (42.3)	
70-90	1,574 (38.71)	1,210 (39.39)	364 (36.66)	
≥90	737 (18.13)	528 (17.17)	209 (21.04)	
Sex				0.943
Male	2,843 (69.92)	2,148 (69.89)	695 (69.99)	
Female	1,223 (30.08)	925 (30.11)	298 (30.01)	
Nervous system	904 (22.23)	681 (22.17)	223 (22.46)	0.826
Respiratory system	203 (4.99)	154 (5.01)	49 (4.93)	0.917
Endocrine system	676 (16.63)	507 (16.51)	169 (17.02)	0.663
Digestive system	716 (17.61)	541 (17.6)	175 (17.62)	0.985
Cardiovascular system	316 (7.77)	238 (7.75)	78 (7.85)	0.899
Urinary system	138 (3.39)	104 (3.4)	34 (3.42)	0.968
ELSE	32 (0.79)	24 (0.78)	8 (0.81)	0.927
Malignant tumor	927 (22.80)	706 (22.97)	221 (22.26)	0.587
Trauma	21 (0.52)	16 (0.51)	5 (0.50)	0.972
Nosocomial Infection	173 (4.25)	154 (5)	19 (1.91)	<0.0001

[a]χ^2 tests were used for the comparison of categorical variables. The test was two-sided and a P<0.05 was considered statistically significant. PSM, propensity score matching; IPTW, inverse probability treatment weight; SMRW, standardised mortality ratio weight.

model with a negative binomial distribution and an unstructured working correlation matrix were used to investigate the longitudinal relationship between interventions and the risk of nosocomial infections. The working correlation matrix constitute the covariance of linear predictor of the generalised linear model which reflect the clustering of the multiple hospitalisations of the same patient. The unstructured working correlation matrix means that no relation assumption of the element in the matrix is assigned, so each element of the correlation matrix should be estimated (54). The baseline characteristics of the 93 patients are listed in Table IV. In total, >90% of the patients were elderly aged >70 years, where 68.82% were male. Nervous system disease was the most common chronic malady in this population

(75.27%). aCCI was used to score comorbidities, where it was found that 67.74% of the patients had higher scores (≥6). Among these inpatients, the risk of nosocomial infections was lower in the intervention group compared with that in the non-intervention group (22.58 vs. 37.63%, respectively; P=0.025), especially the risk of pulmonary infection (13.98 vs. 41.94%, respectively, P<0.001; Table IV).

GEE estimation of the risk of nosocomial infection associated with the interventions. The rates of nosocomial and pulmonary infections were lower in the intervention group compared with those in the non-intervention group based on the univariate analysis (nosocomial infection with GEE adjustment: OR=0.5165, 95% CI=0.2763-0.965 and P=0.0384;

Table II. Multivariate logistic regression analyses for nosocomial infection in IPTW- and SMRW-matched cohort.[a]

A, Unadjusted

Parameter	OR (95% CI)	P-value
Intervention (yes vs. no)	0.36 (0.22-0.59)	<0.0001
Sex (female vs. male)	0.96 (0.68-1.34)	0.7951
Age (vs. <70)		
≥70, <90	2.46 (1.64-3.68)	<0.001
≥90	3.39 (2.14-5.39)	<0.001
Nervous system (yes vs. no)	2.66 (0.36-19.71)	0.339
Respiratory system (yes vs. no)	1.34 (0.17-10.58)	0.783
Endocrine system (yes vs. no)	1.22 (0.15-9.84)	0.849
Digestive system (yes vs. no)	0.94 (0.12-7.27)	0.95
Cardiovascular system (yes vs. no)	1.47 (0.19-11.38)	0.71
Urinary system (yes vs. no)	2.40 (0.29-19.70)	0.415
ELSE (yes vs. no)	1.18 (0.41-3.37)	0.756
Malignant tumor (yes vs. no)	1.98 (0.26-15.08)	0.508
Trauma (yes vs. no)	2.50 (0.25-25.26)	0.437

B, Adjusted with IPTW

Parameter	OR (95% CI)	P-value
Intervention (yes vs. no)	0.33 (0.25-0.44)	<0.0001
Sex (female vs. male)	0.89 (0.68-1.17)	0.4009
Age (vs. <70)		
≥70, <90	2.35 (1.71-3.24)	<0.001
≥90	3.47 (2.42-4.98)	<0.001
Nervous system (yes vs. no)	3.22 (0.66-15.84)	0.15
Respiratory system (yes vs. no)	1.39 (0.26-7.28)	0.7
Endocrine system (yes vs. no)	1.66 (0.32-8.61)	0.545
Digestive system (yes vs. no)	1.39 (0.27-7.05)	0.692
Cardiovascular system (yes vs. no)	2.57 (0.51-12.91)	0.253
Urinary system (yes vs. no)	3.56 (0.67-18.77)	0.135
ELSE (yes vs. no)	0.95 (0.36-2.48)	0.914
Malignant tumor (yes vs. no)	2.94 (0.59-14.64)	0.189
Trauma (yes vs. no)	2.72 (0.40-18.60)	0.307

C, Adjusted with SMRW

Parameter	OR (95% CI)	P-value
Intervention (yes vs. no)	0.35 (0.21-0.61)	<0.0001
Sex (female vs. male)	0.81 (0.46-1.42)	0.463
Age (vs. <70)		
≥70, <90	2.35 (1.23-4.49)	0.01
≥90	3.34 (1.61-6.96)	<0.001
Nervous system (yes vs. no)	2.89 (0.38-22.21)	0.308
Respiratory system (yes vs. no)	1.03 (0.09-11.63)	0.983
Endocrine system (yes vs. no)	1.55 (0.19-12.66)	0.684
Digestive system (yes vs. no)	1.36 (0.16-11.70)	0.778
Cardiovascular system (yes vs. no)	2.51 (0.30-21.22)	0.398
Urinary system (yes vs. no)	3.08 (0.32-29.14)	0.327
ELSE (yes vs. no)	0.83 (0.05-12.82)	0.895
Malignant tumor (yes vs. no)	2.55 (0.33-19.63)	0.37
Trauma (yes vs. no)	2.38 (0.05-112.79)	0.659

[a]95% CI and P-values are based on errors clustered by nosocomial infection. OR, Odds Ratio; Ref, Reference; IPTW, Inverse Probability Treatment Weight; SMRW, Standardised Mortality Ratio Weight; ELSE, Skin system, Oculopathy system, Otolaryngological system, Musculoskeletal system, Rheumatism and Immunity.

Table III. Effect of intervening measures in IPTW-adjusted and SMRW-adjusted logistic regression analyses for the risk of nosocomial infection, stratified according to the age.[a]

Age group (years)	Intervened		Unadjusted		Adjusted with IPTW[b]		Adjusted with SMRW[b]	
	No (n, %)	Yes (n, %)	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
<70	1,567 (50.99)	420 (42.30)	0.48 (0.18-1.27)	0.141	0.39 (0.23-0.68)	<0.001	0.47 (0.16-1.44)	0.189
≥70, <90	1,040 (33.84)	364 (36.66)	0.33 (0.15-0.70)	0.004	0.28 (0.18-0.44)	<0.001	0.34 (0.15-0.76)	0.009
≥90	466 (15.16)	209 (21.05)	0.27 (0.11-0.66)	0.004	0.28 (0.17-0.46)	<0.001	0.26 (0.10-0.68)	0.006
Total	3,039 (75.58)	993 (24.42)	0.36 (0.22-0.59)	<0.001	0.33 (0.25-0.44)	<0.001	0.35 (0.21-0.61)	<0.001

[a]The 95% CI and P-values were calculated based on errors clustered by nosocomial infection. [b]Adjusted with IPTW or SMRW model to adjust for the following: Sex; Nervous system; Respiratory system; Endocrine system; Digestive system; Cardiovascular system; Urinary System; Malignant Tumor; ELSE; and Trauma. CI, Confidence Interval; OR, Odds Ratio; Ref, Reference; IPTW, Inverse Probability Treatment Weight; SMRW, Standardised Mortality Ratio Weight.

Table IV. Baseline characteristics for the longitudinal study of long-stay patients.[a]

Characteristics	Total (n=186), n (%)	Unintervened (n=93), n (%)	Intervened (n=93), n (%)	P-value
Age, years				-
<70	18 (9.68)	9 (9.68)	9 (9.68)	
≥70, <90	76 (40.86)	38 (40.86)	38 (40.86)	
≥90	92 (49.46)	46 (49.46)	46 (49.46)	
Sex				-
Male	128 (68.82)	64 (68.82)	64 (68.82)	
Female	58 (31.18)	29 (31.18)	29 (31.18)	
Nervous system	140 (75.27)	69 (74.19)	71 (76.34)	0.734
Respiratory system	24 (12.9)	14 (15.05)	10 (10.75)	0.382
Endocrine system	72 (38.71)	41 (44.09)	31 (33.33)	0.132
Cardiovascular system	155 (83.33)	78 (83.87)	77 (82.80)	0.844
Malignant tumor	9 (4.84)	3 (3.23)	6 (6.45)	0.305
aCCI				0.754
<6	60 (32.26)	31 (33.33)	29 (31.18)	
≥6	126 (67.74)	62 (66.67)	64 (68.82)	
Gastric catheterisation	66 (35.48)	35 (37.63)	31 (33.33)	0.54
Nosocomial infection	56 (30.11)	35 (37.63)	21 (22.58)	0.025
Pulmonary infection	52 (27.96)	39 (41.94)	13 (13.98)	<0.001
Other infections	16 (8.60)	11 (11.83)	5 (5.38)	0.117

[a]χ^2 tests were used for categorical variables. CCI, age-adjusted Charlson Comorbidity Index.

pulmonary infection with GEE adjustment: OR=0.2186, 95% CI=0.1129-0.4231 and P<0.0001; Table V). In addition, a multivariate logistics regression model was constructed to evaluate the influence of the intervention on the risk of nosocomial and pulmonary infections. Compared with that in the non-intervention group, the intervention group had a lower risk of nosocomial and pulmonary infections (nosocomial infection with GEE adjustment: OR=0.50, 95% CI=0.27-0.90 and P=0.0217; pulmonary infection with GEE adjustment: OR=0.23, 95% CI=0.12-0.42 and P<0.0001) (Table VI). Furthermore, in both the univariate analysis and multiple logistic regression models, gastric catheterisation was found to be a high-risk factor for infection (nosocomial infection with GEE adjustment: OR=2.33, 95% CI=1.12-4.83 and P=0.0229; pulmonary infection with GEE adjustment: OR=3.59, 95% CI=1.69-7.61; P=0.0009; Tables V and VI). Therefore, a stratified analysis for gastric catheterisation was adopted. Among the inpatients without gastric catheterisation, the risk of nosocomial and pulmonary infections was significantly lower in the intervention group compared with that in the non-intervention group after adjusting with GEE in the multiple logistic regression model (nosocomial infection: OR=0.28, 95% CI=0.11-0.61 and P=0.001; pulmonary infection: OR=0.10, 95% CI=0.03-0.32; P<0.001; Table VII).

Table V. Univariate analysis of risk factors for infection based on the GEE model.

A, Nosocomial infection

	Unadjusted		Adjusted With GEE	
Parameters	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.48 (0.25-0.92)	0.027	0.5165 (0.2763-0.9653)	0.038
Sex (female vs. male)	1.07 (0.54-2.09)	0.853	1.2652 (0.5568-2.8747)	0.574
Age (vs. <70)				
≥70, <90	2.04 (0.54-7.74)	0.296	1.1845 (0.2574-5.451)	0.828
≥90	2.54 (0.68-9.44)	0.164	1.0932 (0.2251-5.3079)	0.912
Nervous system (yes vs. no)	2.48 (1.07-5.73)	0.034	1.6831 (0.6924-4.0913)	0.251
Respiratory system (yes vs. no)	1.47 (0.60-3.59)	0.4	1.3962 (0.5328-3.6584)	0.497
Endocrine system (yes vs. no)	1.42 (0.75-2.69)	0.277	1.3131 (0.6176-2.7919)	0.479
Cardiovascular system (yes vs. no)	2.55 (0.92-7.03)	0.07	2.1568 (0.8579-5.4225)	0.102
aCCI (≥6 vs. <6)	1.45 (0.72-2.89)	0.296	1.0225 (0.9371-1.1157)	0.617
Gastric catheterisation (yes vs. no)	2.42 (1.27-4.62)	0.007	2.3313 (1.1242-4.8348)	0.023

B, Pulmonary infection

	Unadjusted		Adjusted With GEE	
Parameters	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.23 (0.11-0.46)	<0.001	0.2186 (0.1129-0.4231)	<0.001
Sex (female vs. male)	0.97 (0.49-1.95)	0.94	1.271 (0.5084-3.1775)	0.608
Age (vs. <70)				
≥70, <90	2.86 (0.60-13.54)	0.186	2.3157 (0.5904-9.0833)	0.229
≥90	3.87 (0.84-17.93)	0.084	2.1334 (0.5572-8.1693)	0.269
Nervous system (yes vs. no)	2.64 (1.10-6.36)	0.031	1.8451 (0.7142-4.7665)	0.206
Respiratory system (yes vs. no)	1.66 (0.68-4.07)	0.268	1.6081 (0.4203-6.1518)	0.488
Endocrine system (yes vs. no)	1.71 (0.90-3.28)	0.104	1.7201 (0.7416-3.9897)	0.206
Cardiovascular system (yes vs. no)	1.76 (0.68-4.57)	0.247	1.3119 (0.4318-3.9863)	0.632
Malignant tumor (yes vs. no)	N/A	N/A	N/A	N/A
aCCI (≥6 vs. <6)	1.62 (0.79-3.33)	0.189	1.0359 (0.9442-1.1364)	0.456
Gastric catheterisation (yes vs. no)	3.31 (1.70-6.43)	<0.001	3.5871 (1.6915-7.607)	<0.001

C, Other infections

	Unadjusted		Adjusted With GEE	
Parameters	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.42 (0.14-1.27)	0.126	0.4421 (0.1489-1.3124)	0.142
Sex (female vs. male)	3.17 (1.12-9.00)	0.03	3.0069 (1.1468-7.8838)	0.025
Age (vs. <70)				
≥70, <90	0.44 (0.07-2.64)	0.372	0.2084 (0.0036-11.9256)	0.448
≥90	0.98 (0.20-4.88)	0.976	0.5239 (0.0066-41.8813)	0.772
Nervous system (yes vs. no)	0.70 (0.23-2.13)	0.529	0.6582 (0.1559-2.7785)	0.569
Respiratory system (yes vs. no)	1.64 (0.43-6.23)	0.469	1.5633 (0.3953-6.1825)	0.524
Endocrine system (yes vs. no)	1.66 (0.59-4.63)	0.336	1.7703 (0.5055-6.2001)	0.372
Cardiovascular system (yes vs. no)	3.21 (0.41-25.28)	0.267	2.4038 (0.2467-23.4249)	0.45
Malignant tumor (yes vs. no)	1.35 (0.16-11.53)	0.784	0.601 (0.01-36.2662)	0.808
aCCI (≥6 vs. <6)	2.19 (0.60-7.98)	0.237	1.0812 (0.9113-1.2828)	0.371
Gastric catheterisation (yes vs. no)	0.39 (0.11-1.43)	0.156	0.3795 (0.0721-1.9981)	0.253

The 95% CI and P-values were calculated based on errors clustered by nosocomial infection, pulmonary infection or other infections. GEE, generalised estimating equation; aCCI, age-adjusted Charlson Comorbidity Index; CI, Confidence Interval; OR, Odds Ratio; Ref, Reference; N/A, not available.

Table VI. Multivariate analysis of risk factors of infection based on the GEE model.[a]

A, Nosocomial infection

Parameters	Unadjusted		Adjusted With GEE	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.50 (0.25-0.97)	0.042	0.50 (0.27-0.90)	0.022
Sex (female vs. male)	1.11 (0.52-2.34)	0.788	1.11 (0.50-2.48)	0.803
Age (vs. <70)				
≥70, <90	1.08 (0.24-4.78)	0.923	1.08 (0.19-5.96)	0.933
≥90	1.17 (0.26-5.33)	0.842	1.17 (0.21-6.59)	0.862
Nervous system (yes vs. no)	1.92 (0.76-4.85)	0.168	1.92 (0.81-4.57)	0.14
Respiratory system (yes vs. no)	1.30 (0.49-3.40)	0.598	1.30 (0.50-3.35)	0.593
Endocrine system (yes vs. no)	1.21 (0.59-2.48)	0.609	1.21 (0.55-2.63)	0.636
Cardiovascular system (yes vs. no)	2.10 (0.71-6.25)	0.183	2.10 (0.81-5.43)	0.126
aCCI (≥6 vs. <6)	1.21 (0.56-2.61)	0.633	1.21 (0.49-3.00)	0.686
Gastric catheterisation (yes vs. no)	2.33 (1.15-4.73)	0.019	2.33 (1.12-4.83)	0.023

B, Pulmonary infection

Parameters	Unadjusted		Adjusted With GEE	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.23 (0.11-0.48)	<0.001	0.23 (0.12-0.42)	<0.001
Sex (female vs. male)	1.02 (0.46-2.28)	0.954	1.02 (0.43-2.42)	0.957
Age (vs. <70)				
≥70, <90	1.78 (0.31-10.14)	0.516	1.78 (0.39-8.11)	0.456
≥90	2.09 (0.36-12.27)	0.414	2.09 (0.47-9.20)	0.329
Nervous system (yes vs. no)	2.16 (0.80-5.82)	0.129	2.16 (0.92-5.04)	0.076
Respiratory system (yes vs. no)	1.43 (0.52-3.94)	0.488	1.43 (0.39-5.21)	0.586
Endocrine system (yes vs. no)	1.46 (0.68-3.15)	0.335	1.46 (0.62-3.43)	0.387
Cardiovascular system (yes vs. no)	1.34 (0.45-3.96)	0.598	1.34 (0.43-4.20)	0.617
CCI (≥6 vs. <6)	1.31 (0.57-3.00)	0.522	1.31 (0.50-3.43)	0.581
Gastric catheterisation (yes vs. no)	3.59 (1.65-7.80)	<0.005	3.59 (1.69-7.61)	<0.001

C, Other infections

Parameters	Unadjusted		Adjusted With GEE	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Intervention (yes vs. no)	0.46 (0.14-1.48)	0.192	0.46 (0.16-1.36)	0.16
Sex (female vs. male)	3.30 (1.00-10.86)	0.049	3.30 (1.17-9.29)	0.024
Age (vs. <70)				
≥70, <90	0.23 (0.03-1.97)	0.181	0.23 (0.01-8.54)	0.427
≥90	0.51 (0.06-4.30)	0.532	0.51 (0.01-21.63)	0.722
Nervous system (yes vs. no)	0.57 (0.15-2.13)	0.4	0.57 (0.14-2.34)	0.432
Respiratory system (yes vs. no)	1.54 (0.33-7.22)	0.585	1.54 (0.38-6.25)	0.547
Endocrine system (yes vs. no)	1.87 (0.57-6.20)	0.303	1.87 (0.53-6.63)	0.33
Cardiovascular system (yes vs. no)	2.42 (0.28-21.26)	0.425	2.42 (0.24-24.77)	0.456
Malignant tumor (yes vs. no)	0.63 (0.04-9.19)	0.737	0.63 (0.02-25.37)	0.807
CCI (≥6 vs. <6)	2.13 (0.50-9.12)	0.31	2.13 (0.43-10.54)	0.356
Gastric catheterisation (yes vs. no)	0.38 (0.10-1.51)	0.169	0.38 (0.07-2.00)	0.253

[a]The 95% CI and P-values were calculated based on errors clustered by nosocomial infection, pulmonary infection or other infections. GEE, generalised estimating equation; CCI, Charlson comorbidity index; CI, Confidence Interval; OR, Odds Ratio; Ref, Reference; N/A, not available.

Table VII. Logistic regression model for the association between intervening measure and infection stratified by gastric catheterisation.[a]

A, Model 0

	Not catherised		Catherterised		Total	
Type of infection	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Nosocomial infection (yes vs. no)						
Unadjusted	0.28 (0.11-0.71)	0.007	0.96 (0.36-2.56)	0.94	0.49 (0.25-0.94)	0.032
Adjusted with GEE	0.28 (0.13-0.60)	<0.001	0.96 (0.35-2.62)	0.941	0.49 (0.27-0.88)	0.016
Pulmonary infection (yes vs. no)						
Unadjusted	0.10 (0.03-0.35)	<0.001	0.40 (0.15-1.10)	0.075	0.21 (0.10-0.45)	<0.001
Adjusted with GEE	0.10 (0.03-0.31)	<0.001	0.40 (0.15-1.11)	0.078	0.21 (0.11-0.40)	<0.001
Other infections (yes vs. no)						
Unadjusted	0.38 (0.11-1.29)	0.121	0.55 (0.05-6.38)	0.633	0.40 (0.13-1.22)	0.109
Adjusted with GEE	0.38 (0.12-1.22)	0.104	0.55 (0.13-2.31)	0.414	0.40 (0.15-1.10)	0.076

B, Model I

	Not catherised		Catherterised		Total	
Type of infection	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Nosocomial infection (yes vs. no)						
Unadjusted	0.25 (0.10-0.66)	0.005	1.00 (0.35-2.82)	0.999	0.49 (0.25-0.94)	0.032
Adjusted with GEE	0.25 (0.11-0.58)	<0.001	1.00 (0.33-3.02)	0.999	0.49 (0.27-0.88)	0.016
Pulmonary infection (yes vs. no)						
Unadjusted	0.09 (0.02-0.32)	<0.001	0.40 (0.14-1.11)	0.077	0.21 (0.10-0.44)	<0.001
Adjusted with GEE	0.09 (0.03-0.30)	<0.005	0.40 (0.14-1.14)	0.086	0.21 (0.11-0.40)	<0.001
Other infections (yes vs. no)						
Unadjusted	0.34 (0.09-1.25)	0.104	N/A	N/A	0.43 (0.14-1.37)	0.154
Adjusted with GEE	0.34 (0.09-1.26)	0.107	0.48 (0.07-3.11)	0.438	0.40 (0.14-1.13)	0.083

C, Model II

	Not catherised		Catherterised		Total	
Type of infection	OR (95% CI)	P-value	OR (95% CI)	P-value	OR (95% CI)	P-value
Nosocomial infection (yes vs. no)						
Unadjusted	0.27 (0.10-0.73)	0.01	1.01 (0.29-3.52)	0.985	0.52 (0.26-1.02)	0.058
Adjusted with GEE	0.27 (0.11-0.61)	0.002	N/A	N/A	0.52 (0.28-0.96)	0.038
Pulmonary infection (yes vs. no)						
Unadjusted	0.10 (0.02-0.37)	<0.001	0.39 (0.12-1.20)	0.099	0.22 (0.10-0.48)	<0.001
Adjusted with GEE	0.10 (0.03-0.32)	0	0.39 (0.12-1.24)	0.111	0.22 (0.11-0.42)	<0.001
Other infections (yes vs. no)						
Unadjusted	0.29 (0.07-1.24)	0.094	N/A	N/A	0.43 (0.14-1.37)	0.154
Adjusted with GEE	0.29 (0.08-1.02)	0.053	N/A	N/A	0.43 (0.15-1.25)	0.122

[a]The 95% CI and P-values were calculated based on errors clustered by nosocomial infection, pulmonary infection, or other infections. Model 0, unadjusted base model. Model I, adjusted for sex and age at baseline. Model II, Model I + adjusted for chronicity disease, malignant tumor and CCI. GEE, generalised estimating equation; CCI, Charlson comorbidity index; CI, Confidence Interval; OR, Odds Ratio; Ref, Reference; N/A, not available.

Predictive model for infection outcomes. Based on the logistic, dichotomous and sequential screening analyses, a nomogram incorporating the risk factors was created for predicting infection outcomes using the EmpowerStats statistical software 2.0 (www.empowerstats.com; X&Y Solutions Inc.), which uses the R packages 'Survival' and
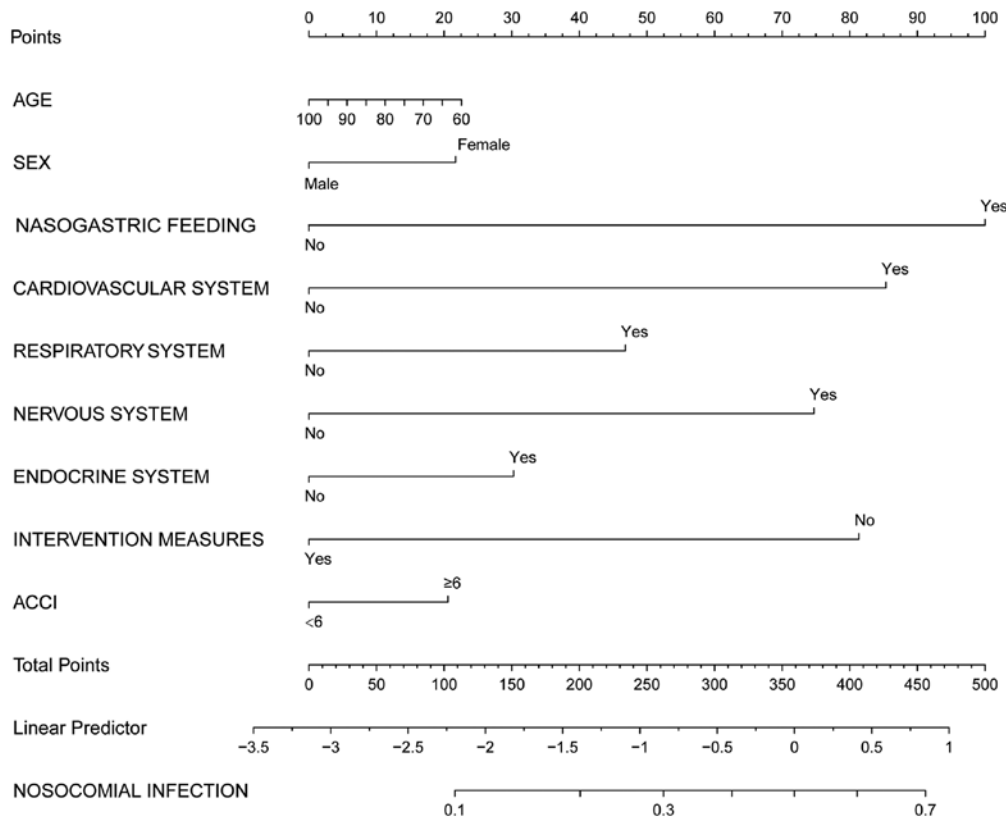
Figure 3. Nomogram of all patients with nosocomial infection. aCCI, age-adjusted Charlson Comorbidity Index.
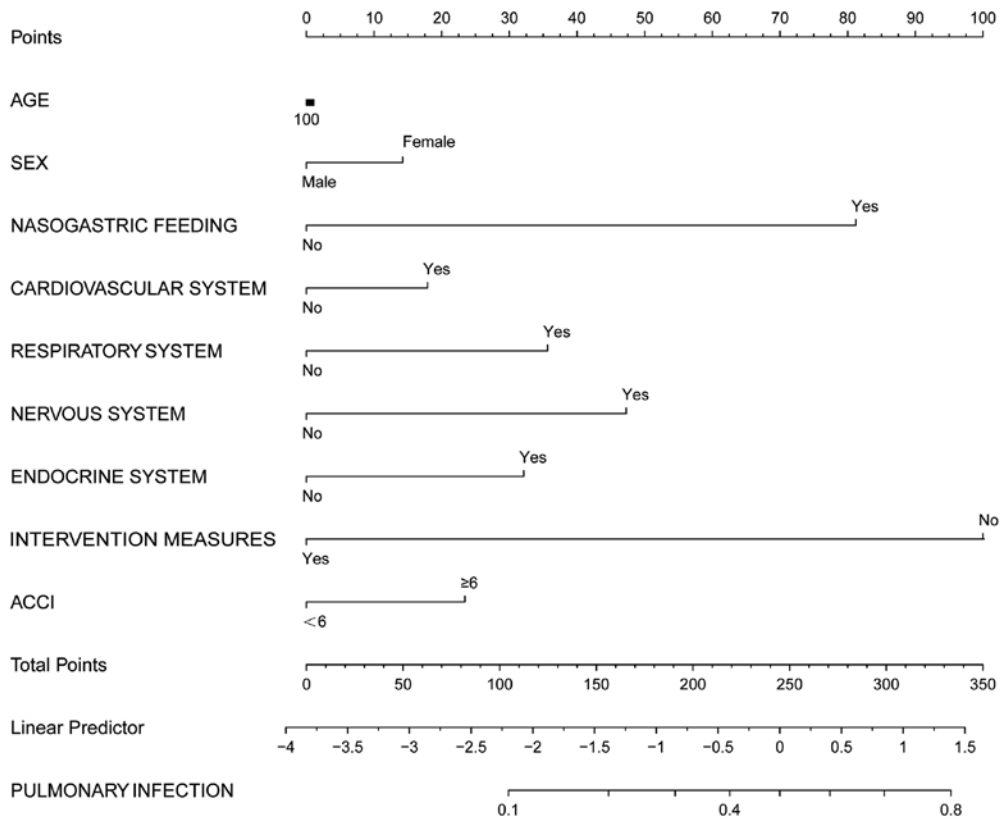
Figure 4. Nomogram of patients with hospital-acquired pneumonia. aCCI, age-adjusted Charlson Comorbidity Index.

'Rms' (R version 3.4.3) to calculate construct the nomograms (Figs. 3-5).

In all patients with infection, a total score was calculated based on age, sex, nasogastric feeding, diseases of the
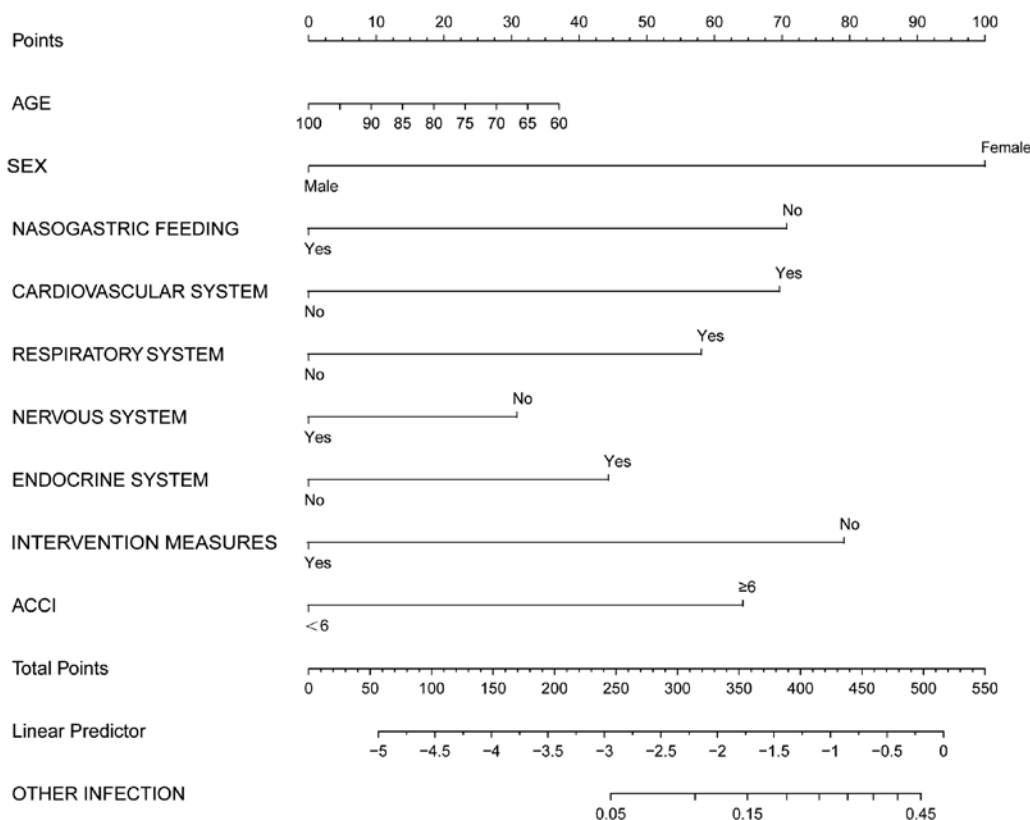
Figure 5. Nomogram of patients with other infections than pneumonia. aCCI, age-adjusted Charlson Comorbidity Index.

cardiovascular, respiratory, nervous and endocrine systems, aCCI and intervention measures. However, the application of this model is relatively complex, therefore it has not been widely applied clinically. Further simplification is required.

Discussion

The novelty of the present study lies in the particularity of the study population. The study site was selected in the geriatric department with a slow turnover, where a large number of elderly inpatients were included into the study population. Elderly inpatients are particularly susceptible to nosocomial infections, especially in the lungs (55,56). Physiological function in the elderly deteriorates over time, with characteristics including decreases in age-related lung function, weakness in the respiratory muscles and loss of the clearance ability in the respiratory mucosa (57). These factors all contribute to increasing the incidence of pneumonia and other chronic diseases, such as chronic obstructive emphysema, chronic pulmonary heart disease and chronic heart failure, among this demographic (57). In addition, since the majority of elderly patients have comorbidities, ≥ one complications may occur based on the disease type. Following cerebrovascular accidents, including cerebral haemorrhage and cerebral infarction, elderly patients are also predisposed to succumbing to aspiration pneumonia, which is a common form of lung infection in elderly patients (58). Furthermore, patients with hemiplegia or those who are chronically bedridden have been reported to be more predisposed to *Streptococcus anginosus*-induced pneumonia (59). Patients

with malignant tumours may also develop radiation pneumonia as a result of long-term radiotherapy (60). Long-term chemotherapy and chronic management using immunosuppressants may impair systemic immune system function, increasing the susceptibility to infection (57). Additionally, patients with malnutrition have diminished pathogen resistance, which increases the risk of infection-related diseases (61). Infection increases the bodily demand for nutrition, further aggravating malnutrition and to establish a vicious cycle (62). In addition, elderly patients frequently display a decreased abilty to perceive their own health status, leading to treatment delays or even mortality (63). In elderly inpatients with pneumonia, the lack of clear clinical symptoms, ambiguous examination and test results, misdiagnosis, delayed treatment and coexistence of malnutrition, coupled with other diseases, all contribute to increasing the risk of lung infection (61). This in turn aggravates illness severity, prolongs the disease course and adds to the difficulty of accurate diagnosis and treatment, leading to irreversible consequences. The diagnosis and treatment of pulmonary infection in elderly inpatients remains a major challenge. Therefore, during the COVID-19 outbreak, appropriate measures were taken to prevent nosocomial infections in elderly patients.

During the pandemic, the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University actively adopted preventive measures. The present retrospective analysis of the selected cases showed that implementing preventive and control measures could effectively control the risk of nosocomial infections. The key finding was the

need to effectively screen patients with infection before hospitalisation to prevent cross-infection. During hospitalisation, it remains important to reduce the flow of people in the hospital, wear masks for protection, effectively cut off the infection source and route of transmission (64). In the present study, preventive measures employed to reduce nosocomial infections in hospitalised patients in the geriatric wards during the COVID-19 pandemic were summarised. Results of the present retrospective analysis revealed that these measures significantly reduced the incidence of nosocomial infection among these patients. Further implementation of these measures may help to effectively control nosocomial infections in the future. Empirical recommendations are required in response to important paroxysmal public health incidents that occur in the future.

In the subgroup study, the nosocomial infection risk of 93 inpatients in the Geriatrics Department of The First Affiliated Hospital with Nanjing Medical University, excluding patients who recently underwent surgery and anti-tumour therapy, was analysed. These 93 patients with long-term stable conditions were selected for longitudinal analysis. The results showed that preventative measures could also effectively control the rate of nosocomial infections in this group. In addition, it was found that the use of indwelling gastric tube was an independent risk factor for nosocomial infections, especially pulmonary infection, among elderly inpatients. Clinically, the majority of elderly inpatients with indwelling gastric tubes also suffer from malnutrition, dysphagia or eating difficulty and severe coughing, all of which have clear indications for gastric tube placement (65). Poor nutritional status is common among elderly patients, especially in those who are hospitalised long-term. This is due to the impaired ability to chew or swallow, which also increases the risk of infection. However, regulating nutrition has been found to contribute to recovery (66-68). Gastric catheterisation is a common treatment method that can be used to effectively improve the nutritional status in the elderly (66). For cerebrovascular accidents, such as cerebral haemorrhage and cerebral infarction, swallowing dysfunction or cognitive impairment may lead to aspiration difficulties, coughing and aspiration pneumonia (69). Aspiration pneumonia is a common subtype of lung infection in elderly patients (58), such that gastric tube placement can effectively prevent aspiration pneumonia. For example, inserting a catheter into the stomach through the nose can reduce the risk of aspiration by eating through the mouth, thereby reducing the risk of aspiration pneumonia. However, the results of the present study revealed that the presence of an indwelling gastric tube was an independent risk factor for pneumonia in elderly inpatients. However, from previous clinical studies (70,71), it is likely that patients with an indwelling gastric tube are more predisposed to pneumonia because of their disease state, rather than the process of gastric tube insertion. Therefore, the focus should be on the placement, disinfection and replacement of the gastric tube, combined with the regular removal of oropharyngeal secretions and good positioning to avoid reflux and aspiration (69). In the present study, participants were patients receiving enteral nutrition who had undergone gastric tube implantation. The results showed that the indwelling gastric tube increased

the risk of nosocomial infections. Nevertheless, nosocomial infections caused by an indwelling gastric tube should either be prevented altogether or at least reduced. Clinically, novel comprehensive nutritional indicators are required to evaluate the efficacy of specific interventions, whereby further research is required to explore the optimal time of intervention and treatment.

In the present study, the preventive and control measures adopted by the Geriatric Department of The First Affiliated Hospital with Nanjing Medical University during the epidemic prevention and control period were discussed. The previous medical environment was retrospectively summarised. In conclusion, epidemic preventative and control measures were able to effectively reduce the occurrence of nosocomial infections in elderly inpatients. However, owing to the limited research data from retrospective studies, the study participants in the present study also had regional limitations. Therefore, the results obtained may not apply to all geographic regions. It is necessary to further expand the sample collection area and conduct prospective multi-centre studies to improve upon existing measures. The ultimate aim should be to gradually establish a mature medical management system that is not limited to the prevention and control of the epidemic. This will certainly contribute to the prevention of nosocomial infections or reduction of their incidence in the future.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Authors' contributions

SSW, WL and MJZ conceived and designed the current study. MJZ, WL, SSW, KW, QS and YJH acquired, analyzed the data and interpreted the data. MJZ, WL, JL and SSW performed statistical analysis. ML, SRS and BC participated in the acquisition of data (including screening of enrolled patients and collection of test indicators required for the study). JQW designed the study and interpreted the data. WL and KW confirm the authenticity of all the raw data. All authors critically revised the manuscript for important intellectual content, and read and approved the final version of the manuscript.

Ethics approval and consent to participate

The present study was approved by the Ethics Committee of the First Affiliated Hospital with Nanjing Medical University (approval no. 2020-SR-072; Nanjing). The institutional review

board of the The First Affiliated Hospital with Nanjing Medical University approved this study and granted a waiver of informed consent from study participants because of the retrospective nature of the present study. In the present retrospective study, patient data were obtained through the electronic medical record system.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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