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Preoperative predictors of mortality in fractures of the proximal femur

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ABSTRACT

BACKGROUND: Age and comorbidities are considered independent preoperative predictors of mortality in proximal femoral fractures; however, their contribution remains debatable.

AIM: To assess the prognostic significance of age and Charlson Comorbidity Index (CCI) of the survival of older people with proximal femoral fractures.

MATERIALS AND METHODS: This retrospective prospective study included all cases of proximal femoral fractures that occurred between January 1, 2019, and December 31, 2019, in individuals over 50 years of age from the cities of Tver, Torzhok, Rzhev, VyshnyVolochek, and Kashin. ICD-10 codes: S72.0, S72.1, and S72.2. The CCI of each patient was calculated using an online calculator and clinical data obtained from patient and outpatient records. Statistical analysis. Survival was estimated using Kaplan–Meier curves and the average number of deaths per day per 1000 people. The follow-up interval was obtained in days from the time of injury to the event of death or last contact with the patient. The minimum observation period was 876 days, and the maximum was 1492 days.

RESULTS: The survival rate of patients decreased from younger to older age groups, both among those operated on and those who were not. Patients aged ⩾85 years were at greatest risk (median survival: 257 days; 95% CI: 36.6–478.3). CCI was significantly associated with survival: the risk of death with CCI >3 was 3–6 times higher than that with CCI 2–3, depending on the follow-up interval. CCI reflected health status more than age: within the same age group, there were patients with different CCIs.

CONCLUSION: Using age and CCI simultaneously as predictors of mortality and more accurate indicators of health status will enable the planning of the utilization of additional medical and social resources in the preoperative and postoperative periods, thereby increasing survival.

Keywords: Charlson index; proximal femur fracture; survival; mortality.

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Дооперационные предикторы летальности при переломах проксимального отдела бедренной кости

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АННОТАЦИЯ

Обоснование. Возраст и коморбидность рассматриваются как независимые дооперационные предикторы летальности при переломах проксимального отдела бедренной кости, однако их вклад остаётся предметом дискуссии.

Цель. Оценить прогностическую значимость возраста и индекса Charlson CCI для выживаемости лиц старших возрастных групп при переломах проксимального отдела бедренной кости.

Материалы и методы. Ретроспективно-проспективное исследование с включением всех случаев переломов проксимального отдела бедренной кости (коды по МКБ-10: S72.0, S72.1, S72.2), имевших место с 1 января по 31 декабря 2019 года у лиц старше 50 лет городов Твери, Торжка, Ржева, Вышнего Волочка и Кашина. Индекс Charlson для каждого пациента рассчитан с помощью онлайн-калькулятора и использования клинических данных, полученных из историй болезни и амбулаторных карт пациентов. Выживаемость оценивалась с помощью кривых Каплана–Мейера и среднего количества смертей в день на 1000 человек. Интервал наблюдения рассчитывался в днях с момента травмы до события смерти или последнего контакта с пациентом. Минимальный срок наблюдения составлял 876 дней, максимальный — 1492 дня.

Результаты. Выживаемость пациентов закономерно снижалась от менее возрастной к более возрастной группе как среди оперированных, так и неоперированных. Возраст наибольшего риска летальности — 85 лет и старше (медиана выживаемости — 257 дней, 95% ДИ 36,6–478,3). CCI значимо связан с выживаемостью: риск смерти при CCI >3 баллов выше по сравнению с CCI 2–3 балла в зависимости от интервала наблюдения в 3–6 раз. В исследуемой популяции CCI в большей степени, чем возраст, отражал состояние здоровья: в одной возрастной группе были пациенты с разным CCI.

Заключение. Применение в качестве предикторов летальности одновременно возраста и CCI как более точного показателя состояния здоровья позволит запланировать использование в дооперационном и раннем послеоперационном периоде дополнительных медицинских и социальных ресурсов и тем самым повысить выживаемость.

Ключевые слова: индекс Charlson; перелом проксимального отдела бедра; выживаемость; летальность.

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BACKGROUND

Proximal femoral fractures (PFFs) in older people are a common cause of mortality [1]; therefore, assessing its risk and survival expectations is important when deciding on the treatment approach. This information is important for older people who have the most pronounced comorbidity [2]. Age, male sex, residence in a nursing home, and multiple concomittant diseases are most often considered preoperative independent predictors of mortality in PFF [3]. However, no evidence confirms the influence of each of them on 1-year and mid-term mortality rates. Therefore, the need for continued research is emphasized, and this most concerns the assessment of predictors such as age and comorbidity [1, 4–7].

This study aimed to assess the prognostic significance of age and the Charlson index for the survival rate of patients with PFF aged >50 years. The primary and secondary endpoints of the study were the 1-year survival rate and the 2- and 3-year survival rates, respectively.

MATERIALS AND METHODS

Study design

A retrospective and prospective study was conducted.

Eligibility criteria

All patients with PFF had ICD-10 diagnosis codes S72.0 (femoral neck fracture), S72.1 (pertrochanteric fracture), and S72.2 (subtrochanteric fracture).

Conditions

The study was conducted from January 1 to December 31, 2019, and included patients who applied to the emergency department of the clinic and/or were hospitalized in the trauma departments of the cities of Tver, Torzhok, Rzhev, Vyshny Volochyok, and Kashin.

Methods for recording outcomes

Information for assessing outcomes was obtained through telephone contact (one time) with the patient or his/her relatives. If the telephone contact did not happen (call not answered), the patient's death was excluded or confirmed by data from the regional BARS system (operating since the end of 2019) or the federal notary chamber. The follow-up interval was calculated in days from the time of injury to the death or the last contact with the patient. The minimum and maximum follow-up periods were 876 and 1492 days, respectively.

To predict mortality, the Charlson comorbidity index (CCI) was used along with age. As a final indicator of a patient's multimorbid status, the CCI was calculated in points using an online calculator, which included data on associated comorbidity categories, each of which has a corresponding score (from 1 to 6) with an adjusted mortality risk and added a score corresponding to the patient's age (attached in calculator per every 10 years). In this study, data obtained from medical records or outpatient records were entered into an online calculator. The analysis included 443 cases of fracture, 111 and 332 of which were treated surgically and conservatively, respectively; therefore, the effects of age and CCI on survival were assessed separately for the operated and nonoperated groups. The number of patients in the operated group decreased significantly with age (p <0.001, Pearson's χ^2 test). After the follow-up period, 239 out of 443 patients remained alive, and 204 patients died. The cumulative mortality rates after 1, 2, and 3 years were 6.3%, 11.7%, and 15.3% in the operated group and 32.5%, 44%, and 57.5% in the conservative group, respectively. The survival rate for different types of treatment was not compared because in surgical treatment, survival was also influenced by predictors such as the surgery itself and the duration of the preoperative period.

Statistical analysis

IBM SPSS Statistics for Windows version 23 (IBM Corp., Armonk, NY, USA) was used. Pearson's χ^2 test was used to assess the relationship between ordinal or nominal variables. The pairwise correlation coefficient was calculated using the Spearman method. Receiver operating characteristic (ROC) and Kaplan–Meier curves were used to distribute the patients into groups by age and CCI, respectively. The patient survival rate was studied using the Kaplan–Meier method. The probability of survival to a certain date was given with a 95% confidence interval. The minimum and maximum follow-up periods were 876 and 1492 days, respectively. Patients lost to follow-up before the maximum period expiration were censored (on the right). Pairwise comparisons were assessed using the log-rank test. The average number of people per day who died at a random interval was calculated using the equation:

$$Q \text{ (patients)} = \frac{A \times 1000}{L \times (N - a)},$$

where A is the number of deaths in the interval, L is the interval duration in days, N is the initial number of patients in the group analyzed, a is the number of patients who died in previous time intervals, and Q is the average number of patients who died in the interval per day per 1000 people in a group.

Ethical considerations

The study complied with ethical standards of the Declaration of Helsinki of the World Association "Ethical Principles for Scientific Medical Research Involving Human Subjects" as amended in 2000 and the "Rules for Clinical Practice in the Russian Federation" approved by the Order of the Ministry of Health of the Russian Federation No. 266 of June 19, 2003.

RESULTS

Age and survival rate

ROC curves (area, 0.670) were used to obtain the age groups that differed most in survival. The critical points of ⩽77 years (group 1), ⩾78 years (group 2), and ⩾85 years (group 3) were obtained.

Table 1 presents the number of patients in the selected age groups and death cases by the end of the follow-up period in the nonoperated and operated groups. The survival rates of patients by age groups are presented in Figs. 1 and 2 for the nonoperated and operated groups, respectively.

In the nonoperated group (Fig. 1), pairwise comparisons revealed that the survival period in group 1 was significantly longer than those in groups 2 and 3 (p=0.001 and p <0.001, respectively). The survival rate in group 2 was significantly different from that in group 3 (p <0.001, log-rank test). The median survival rate in group 1 was not reached at the end of follow-up, while it was reached by day 973 in group 2 (95% CI 613.6–1332.4) and day 257 in group 3 (95% CI 36.6–478.3).

In the operated group (Fig. 2), the survival rate in group 1 was significantly greater than that in group 2 (p <0.001, log-rank test). In group 3, only three patients underwent surgery; therefore, statistical analysis was not performed. The median survival in both groups 1 and 2 was not reached during the follow-up interval. The average number of deaths per day separately for the operated and nonoperated groups is presented in Table 2.

In the nonoperated group (Table 2), the average number of deaths per day was the greatest in the first 90 days; and among those aged >85 years, the number was significantly higher than those in the other two groups. If in group 1 this indicator decreased significantly at subsequent intervals, then in group 2 and, particularly, in group 3, it remained elevated at all follow-up intervals. In the operated group, the average number of deaths per day in group 1 was low throughout the follow-up period; in group 2, it was slightly higher and practically did not change during the first 2 years; a downward trend was noted only in year 3. Estimating the indicator in the group aged >85 years of

Table 1. Proximal femur fracture outcomes in selected age groups, operated and unoperated patients by the end of follow-up period

Surgery	Age groups	All patients	Death counts	Quantity	
				n	**%**
No	1st	133	49	84	63.2
	2d	114	66	48	42.1
	3rd	85	70	15	17.6
	All	332	185	147	44.3
Yes	1st	87	10	77	88.5
	2d	21	7	14	66.7
	3rd	3	2	1	33.3
	All	111	19	92	82.9

Note. Group 1 — under 77 years old, group 2 — 78–84 years old, and group 3 — 85 years old and over.

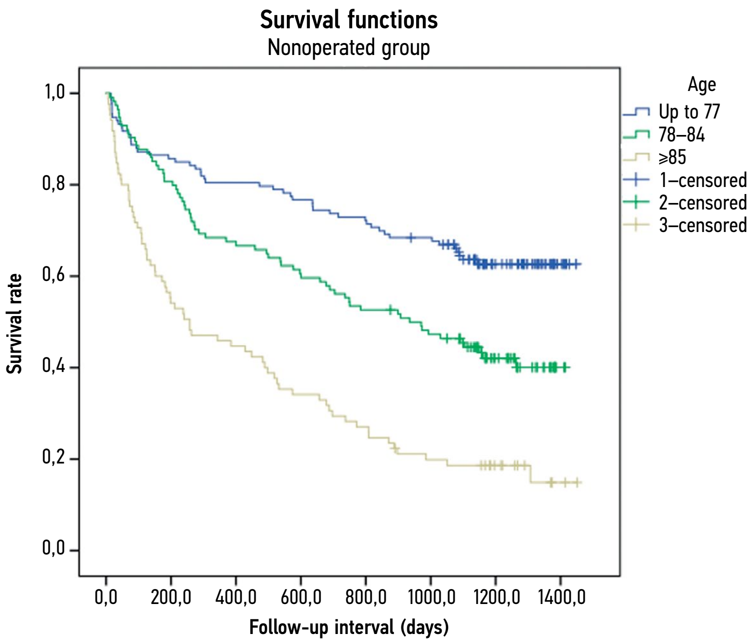

Fig. 1. Kaplan-Meier survival curves of unoperated patients in selected age groups.

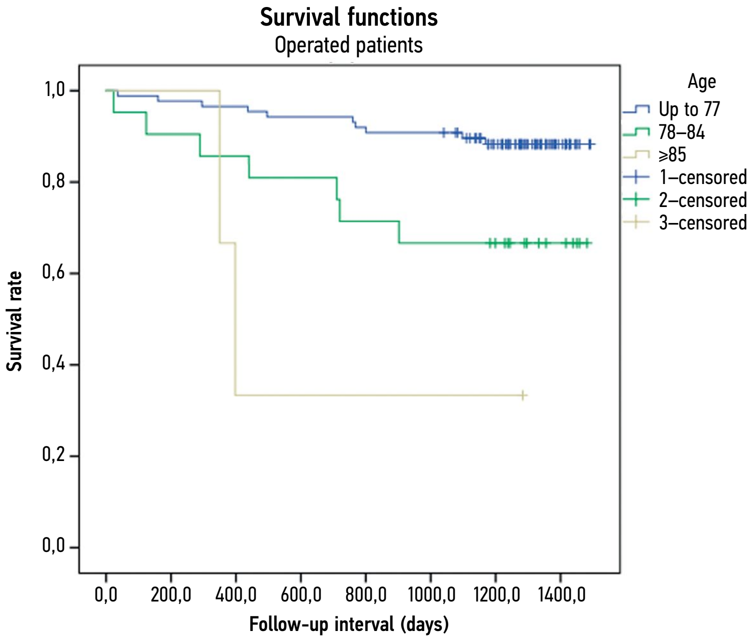

Fig. 2. Kaplan-Meier survival curves of operated patients in different age groups.

Table 2. Average number of deaths per day in selected age groups per 1000 people at different time intervals among unoperated and operated patients

Follow-up period (days) / Age groups	90		91–365		366–730		731–1492	
	Unoper.	**Oper.**	**Unoper.**	**Oper.**	**Unoper.**	**Oper.**	**Unoper.**	**Oper.**
Up to 77 years	1.25	0.13	0.34	0.08	0.26	0.07	0.31	0.1
78–84 years	1.17	0.53	0.85	0.36	0.79	0.45	0.57	0.18
85 years and older	3.13		1.20		0.78		0.86	

age was not possible because surgery was practically not performed in patients of this age in the study sample. In year 1, the number of deaths per day in the group aged 78–84 years was four times higher than that in the group aged ⩽77 years.

Influence of the CCI on the survival rate

The influence of the CCI, as well as age, on the survival rate was assessed separately in the operated and nonoperated groups. The division according to the CCI was performed based on the principle of obtaining the greatest differences between groups according to the survival curves (up to 3 points in group 1, 4–8 points in group 2, and ⩾9 points in group 3). The number of patients in the CCI groups and death cases by the end of the follow-up period in the nonoperated and operated groups are presented in Table 3. The survival curves for patients with different CCIs are presented in Figs. 3 (nonoperated) and 4 (operated).

Table 3. Patients and outcomes of proximal femoral fracture in the Charlson index-designated groups by the end of follow-up period

Surgery	Groups	Total	Death counts	Quantity	
				n	%
No	1	25	5	20	80.0
	2	209	112	97	46.4
	3	98	68	30	30.6
	All	332	185	147	44.3
Yes	1	36	2	34	94.4
	2	68	14	54	79.4
	3	7	3	4	57.1
	All	111	19	92	82.9

Note. Group 1 — up to 3 points, group 2 — 4–8 points, group 3 — 9 or more points.

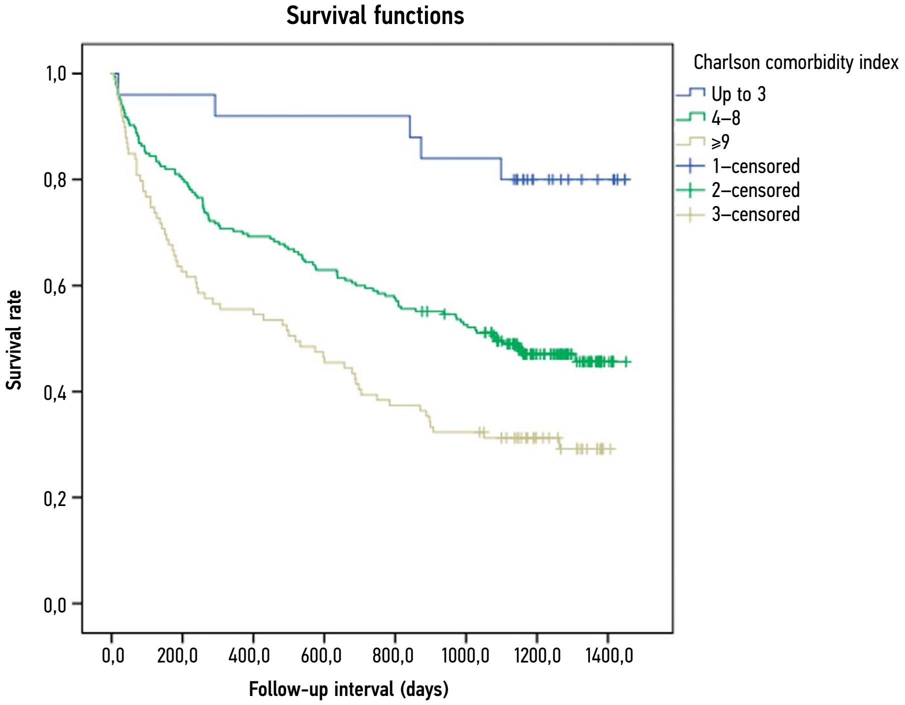

Fig. 3. Kaplan-Meier survival curves of unoperated patients with different Charlson comorbidity index.

Paired comparisons of the patients in the nonoperated group (Fig. 3) revealed that survival in the group with CCI up to 3 points was significantly higher than that in groups 2 and 3 (p=0.003 and p <0.001, respectively). In group 2, the value was higher than that in group 3, p=0.003 (log-rank test). In group 1, median survival was not reached by the end of the follow-up period; in group 2, it was achieved by day 1081 (95% CI 758.9–1403.1); and in group 3, it was achieved by day 518 (95 % CI 207.5–828.5).

In the operated group, pairwise comparisons of groups with different CCI (Fig. 4) revealed that in group 1, the survival rate was significantly higher than those in groups 2 and 3 (p=0.041 and p=0.001, respectively, log-rank test). The differences between groups 2 and 3 were statistically not significant (possibly because of the small number of follow-up cases in group 3). The median survival in the groups was not reached at the end of the follow-up period.

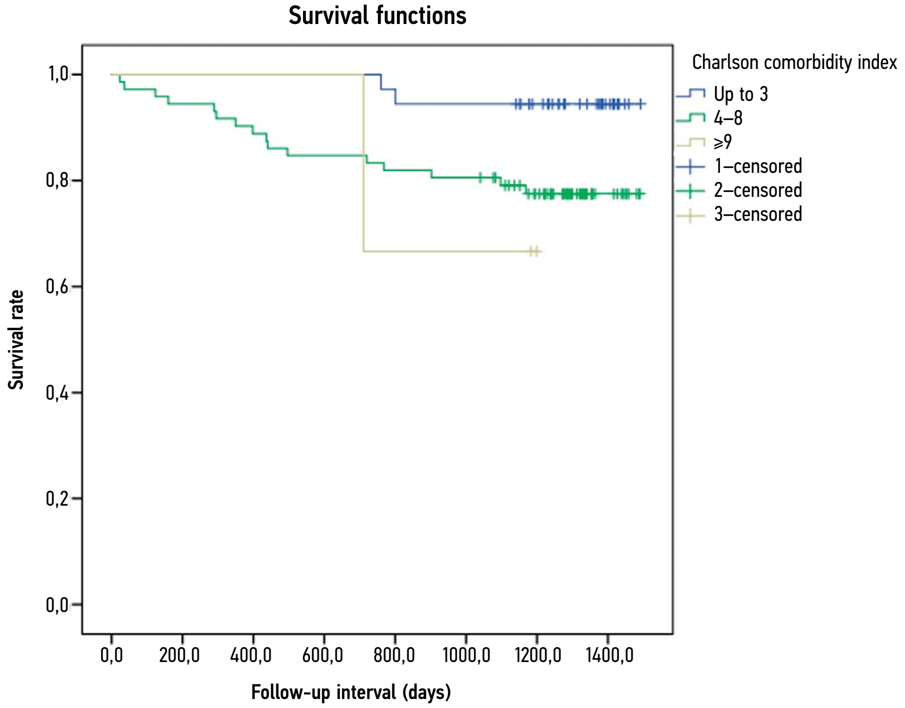

Fig. 4. Kaplan-Meier survival curves of operated patients with different Charlson comorbidity index.

Just as in age groups, in groups with different CCIs, the average number of deaths per day (per 1000 patients) was assessed at the indicated time intervals and separately for the nonoperated and operated groups (Table 4).

The average number of deaths (Table 4) in the nonoperated group was the highest in all groups in the first 90 days, increasing in groups 2 and 3 relative to group 1 by 3.7 and 5.6 times, respectively. At subsequent time intervals, the number of deaths remained low in group 1; a downward trend was noted after year 1 in group 2 and only after 2 years in group 3. Among patients in the operated group with a CCI score of 0–3 points, the survival rate for the first 2 years was 100%; in those with a CCI score of 4–8 points, the survival rate was slightly lower and did not change significantly over the follow-up intervals. Only seven patients were included in the group with a CCI of ≥9 points; thus, no analysis was performed.

When comparing the age groups and groups distributed by CCI (Table 5), patients with CCI of up to 3 points were only found in the group aged ≤77 years in both the operated and nonoperated groups. However, even in this age group, most patients had a CCI of 4–8 points (nonoperated group, 72.9%; operated group, 56.3%). In the group aged 78–84 years, patients with CCI scores of 4–8 predominated (nonoperated group, 60.5%; operated group, 76.2%). In this age group, 23.8% of the patients had CCI of ≥9 among patients who underwent surgery. As for the group aged ≥85 years, half of the patients had CCI of 4–8 points, and half had CCI of ≥9 points, and they received surgical treatment extremely rarely. The median survival of patients with aged ≥85 years and CCI of ≥9 points was 185 days (95% CI 91–280). The correlation between age and CCI in the study sample was 0.635 (Spearman correlation).

DISCUSSION

During the treatment planning period for patients with PFF, age is often used to assess survival. Thus, survival after PFFs decreases significantly in people aged ≥65 years [10–12], which was confirmed in our sample, as the survival rate in both the operated and nonoperated groups naturally decreased from younger to older age. Patients aged ≥85 years (in our sample, patients of this age were among those who had not undergone surgery) belonged to

Table 4. Mean number of mortality per day / 1000 people among unoperated and operated patients with different Charlson index at the analyzed time intervals

Follow-up period (days) / Groups by Charlson index	90		91–365		366–730		731–1492	
	Unoper.	Oper.	Unoper.	Oper.	Unoper.	Oper.	Unoper.	Oper.
Up to 3 points	0.44	0.0	0.15	0.0	0.12	0.0	0.12	0.15
4–8 points	1.63	0.3	0.64	0.26	0.42	0.21	0.45	0.09
9 and more points	2.47		0.78		0.97		0.56	

Table 5. Comparison of age groups with groups divided by the Charlson index

Surgery			Charlson index 1st	2d	3rd	Total
No	Age groups	1st	25	97	11	133
			18.8%	72.9%	8.3%	100.0%
		2d	0	69	45	114
			0.0%	60.5%	39.5%	100.0%
		3rd	0	43	42	85
			0.0%	50.6%	49.4%	100.0%
	Total		25	209	98	332
			7.5%	63.0%	29.5%	100.0%
Yes	Age groups	1st	36	49	2	87
			41.4%	56.3%	2.3%	100.0%
		2d	0	16	5	21
			0.0%	76.2%	23.8%	100.0%
		3rd	0	3	0	3
			0.0%	100.0%	0.0%	100.0%
	Total		36	68	7	111
			32.4%	61.3%	6.3%	100.0%

the highest-risk group because half of the patients in the nonoperated group did not survive 1 year (median survival, 257 days, 95% CI 36.6–478.3), whereas in the group aged 78–84 years, 50% of the patients survived for 2.5 years; and in the group aged ⩽77 years, the median survival rate was not reached in both the operated and nonoperated groups, even by the end of the follow-up period. The average number of deaths per day among patients aged ⩾85 years was also significantly higher at all follow-up intervals than among other age groups. According to some data, the risk of mortality increases sharply at the age of 83.4 years [13]; according to our sample, this belonged to the age of ⩾85 years. However, according to some authors, the role of age as a mortality predictor is limited. Thus, N.H. Varady et al. [14] demonstrated that in the case of PFF, CCI surpasses the role of not only individual concomitant diseases but also age in assessing the mortality risk. CCI has been used as an indicator of mortality since 1987 [15]. Although the CCI assessment was not initially intended for patients with PFF, its high prognostic significance has now been revealed in this pathology [14, 16].

The CCI assessment performed in this study primarily revealed that patients with PFF had a low level of health status because all patients with CCI of 2–3 points belonged to the age group ⩽77 years. Moreover, most patients in this age group in both the nonoperated (72.3%) and operated (56.3%) groups, had a CCI of 4–8 points or even ⩾9 points (8.3% and 2.3%, respectively).

According to some data, an increase in CCI from 1–2 to 3–4 points increases the 1-year mortality rate in patients with PFF from 26% to 52% [17]; with a CCI of ⩾4 points, the risk of death compared with a CCI of 2–3 points increases from 3.1 to 8.5 times [16]. Other researchers also noted a decrease in survival with CCI of ⩾4 points [18]. With a CCI score of ⩾4 points, the 65-year survival rate is two times lower than the survival rate of individuals with a CCI score of ⩽3 points [17]. This also applies to the 10-year survival rate [2]. In our sample, the survival rate of patients with CCI up to 3 points was significantly higher than those of the groups with CCI of 4–8 and CCI of ⩾9 points in both the nonoperated and operated groups (p=0.041, p=0.001, respectively), which was manifested by the median survival of the compared groups and the average number of deaths per day per 1000 people. This indicator increased from group 1 to groups 2 and 3 by ⩾3 times, depending on the follow-up interval.

Other criteria, such as the American Society of Anesthesiologists (ASA) physical status classification, are also used to assess mortality risk. However, according to available data [19], the predictive value of CCI is the highest among all predictors of mortality, and its assessment can, among other things, influence unpopular decisions such as the decision not to perform surgery on a patient [20]. Regarding the use of an indicator such as ASA [21] to assess the mortality risk in PFF, evidence [14] shows that CCI in assessing 90-day and 1-year mortality shows more accurate results than ASA (accuracy is higher by 42% for 90-day mortality and by 112% a 1-year mortality).

In our population-based sample, a statistically significant correlation was found between age and CCI. However, each of them can only be one of the mortality risk criteria because, in the same age group, there may be patients with different CCI, which affects survivability regardless of age.

Study limitations

The study limitations are associated with its retrospective nature because the researchers were forced to rely on medical records taken by other doctors, and there could be more comorbidities than recorded. In addition, potential interfering factors that could affect the results, such as intake of medications, smoking, and postoperative care, were not controlled.

CONCLUSION

Patients aged ⩾85 years with CCI ⩾9 points had the highest risk of PFF-related mortality. The median survival of these patients was 185 days (95% CI 91–280). The simultaneous use of age and CCI as a mortality predictor, as a more accurate indicator of health status, will help in planning the use of additional medical and social resources in the preoperative and early postoperative periods and thereby improve 1-year and medium-term survivability in patients with PFF.

ADDITIONAL INFO

Author contribution. All authors made a substantial contribution to the conception of the work, acquisition, analysis, interpretation of data for the work, drafting and revising the work, final approval of the version to be published and agree to be accountable for all aspects of the work.

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Competing interests. The authors declare that they have no competing interests.

ДОПОЛНИТЕЛЬНО

Вклад авторов. Все авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией).

Источник финансирования. Авторы заявляют об отсутствии внешнего финансирования при проведении исследования и подготовке публикации.

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с проведённым исследованием и публикацией настоящей статьи.

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