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ORIGINAL COMMUNICATION

One-year survival of patients with high-grade glioma discharged alive from the intensive care unit

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Abstract

Introduction Only limited data are available regarding the long-term prognosis of patients with high-grade glioma discharged alive from the intensive care unit. We sought to quantify 1-year mortality and evaluate the association between mortality and (1) functional status, and (2) management of anticancer therapy in patients with high-grade glioma discharged alive from the intensive care unit.

Patients and methods Retrospective observational cohort study of patients with high-grade glioma admitted to two intensive care units between January 2009 and June 2018. Functional status was assessed by the Karnofsky Performance Status. Anticancer therapy after discharge was classified as (1) continued (unchanged), (2) modified (changed or stopped), or (3) initiated (for newly diagnosed disease).

Results Ninety-one high-grade glioma patients (73% of whom had glioblastoma) were included and 78 (86%) of these patients were discharged alive from the intensive care unit. Anticancer therapy was continued, modified, and initiated in 41%, 42%, and 17% of patients, respectively. Corticosteroid therapy at the time of ICU admission [odds ratio (OR) 0.07] and cancer progression (OR 0.09) was independently associated with continuation of anticancer therapy. The mortality rate 1 year after ICU admission was 73%. On multivariate analysis, continuation of anticancer therapy (OR 0.18) and Karnofsky performance status on admission (OR 0.90) were independently associated with lower 1-year mortality.

Conclusion The presence of high-grade glioma is not sufficient to justify refusal of intensive care unit admission. Performance status and continuation of anticancer therapy are associated with higher survival after intensive care unit discharge.

Previous presentation Preliminary results were presented at the most recent congress of the French Intensive Care Society, Paris, 2019.

Keywords Malignant brain tumors · Glioma · One-year survival · Intensive care unit · Anticancer therapy · Performance status

Introduction

Patients with solid tumor or hematologic malignancies account for 20% of intensive care unit (ICU) admissions [1, 2]. Because the prognosis of cancer patients is similar to that of non-cancer patients [1, 3], a diagnosis of cancer should not preclude ICU admission. This general rule also applies to patients with primary malignant brain tumors admitted to the ICU [4].

The outcome of patients with primary malignant brain tumors has been described in terms of short-term and medium-term mortality [4–6]. However, data on 1-year mortality in these patients discharged alive from the ICU are lacking [3–7], and previous series included mixed high-grade gliomas (HGG), low-grade gliomas, and primary central nervous system lymphomas which have a heterogeneous prognosis [4–6]. In addition, the impact of an ICU stay on health-related performance status and the opportunity to continue anticancer therapy remains unclear [8–11]. These last two points are of utmost importance, as a marked reduction of performance status is commonly observed in patients

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requiring mechanical ventilation or vasopressors [12–16]. In turn, this poor performance status at ICU discharge may jeopardize long-term outcome by postponing or canceling anticancer therapy [10, 11]. This risk is particularly high in patients with primary malignant brain tumors, as these tumors are known to reduce performance status [17–19], especially in patients with HGG.

We designed the present study to identify factors associated with 1-year outcomes in patients with HGG who survived an unplanned medical ICU stay. In addition, we examined changes in performance status and changes in the management of anticancer therapy after ICU discharge. This study focused on a homogeneous population of HGG, corresponding to majority of primary brain tumors with the most severe prognosis and raising the most challenging decisions concerning ICU admission. Our hypotheses were that, among HGG patients discharged alive from the ICU: (1) a substantial proportion of patients would still be alive 1 year after ICU discharge, with relatively good performance status, (2) anticancer therapy could be continued in a substantial proportion of patients, and (3) the performance status at ICU admission and maintenance of anticancer therapy were associated with a higher 1-year survival rate.

Patients and methods

Study design and settings

The study was conducted from January 2009 to June 2018 in two medical ICUs: a 16-bed ICU in a pulmonology department and a 16-bed ICU in a neurology department. Both ICUs are located in a university hospital with a strong neurological orientation including a specific neuro-oncology department (about 500 newly diagnosed patients each year) and the national reference center for high-grade oligodendroglial tumor (i.e., POLA Network). This study was approved by the French Intensive Care Society Institutional Review Board (CE SRLF 20-15) and information was given to the patients or their relatives. Data from this cohort have been previously published [4, 6].

Patient selection

Data were extracted from a prospectively managed database that comprehensively describes all patient stays in the two ICUs (Fusion, Varimed, France). The database of the two ICUs comprised 6,437 records, corresponding to 100% of admissions over the study period. In patients with several readmissions, only the first stay was included in the analysis. This set of 6,437 records was retrospectively searched for all consecutives cases of HGG, defined as grade III (anaplastic astrocytoma and oligodendroglioma) and grade IV (glioblastoma) glioma according to the 2016 World Health Organization (WHO) Classification of Tumors of the Central Nervous System [20]. Patient who underwent recent neurosurgery (< 2 weeks) or any other recent surgery (< 4 weeks) and patients under the age of 18 years were excluded.

Data collection

At the time of admission, gender, age, comorbidities using the Charlson Comorbidity Index (CCI) [21], physiological variables such as body temperature, respiratory rate, heart rate, systolic blood pressure, and Glasgow coma scale and various laboratory variables were recorded. Severity on admission was assessed by the Simplified Acute Physiology Score (SAPS) II [22] and the Sequential Organ Failure Assessment (SOFA) [23]. Performance status was assessed during the week before ICU admission and 1, 3, 6, 9, and 12 months after ICU admission, using the Karnofsky Performance Status Scale [24]. The tumor type was determined histologically on either the resection specimen or a biopsy. IDH 1/2 mutation and 1p/19q codeletion molecular status were also collected when available (systematic testing in our center since 2013). The reason for admission was determined retrospectively from the conclusions of the medical records. In case of admission for coma, the diagnosis of seizures was adopted when abnormal movements highly suggestive of seizures were observed, with or without electroencephalographic confirmation, or in the absence of suggestive movements, by consciousness alteration associated with electroencephalographic confirmation of seizures. Cancer disease status was classified as controlled (partial response, complete response, or stable disease), in progression, or newly diagnosed when the cancer was diagnosed during or after ICU admission or when the cancer was diagnosed during the 2 weeks preceding the ICU stay and no anticancer therapy had yet been delivered. Anticancer therapy after ICU discharge was classified as follows: (1) *continued*, when the anticancer therapy planned and initiated before ICU admission was continued unchanged after ICU discharge, (2) *modified,* when the anticancer therapy planned and initiated before ICU admission was changed or stopped after ICU discharge, and (3) *initiated*, when, for patients with newly diagnosed cancer, anticancer therapy was initiated during or after the ICU stay. Anticancer therapy only comprised chemotherapy and radiation therapy. We also recorded whether or not patients were receiving corticosteroid therapy at the time of ICU admission. The presence of corticosteroids at admission was not considered to constitute anticancer therapy. Finally, advanced life support measures taken during the ICU stay and vital status 1 year after ICU admission (1-year mortality) were recorded.

Statistical analysis

Continuous variables were reported as median and interquartile interval, and categorical variables were reported as frequencies (%). Categorical variables were compared using the Chi-square test or Fisher's exact test, as appropriate. Continuous variables were compared using the Mann–Whitney test or the Kruskal–Wallis test. All tests were two-sided and p values < 0.05 were considered statistically significant. Multivariate logistic regression was performed to identify factors associated with one-year mortality after ICU admission. In patients receiving anticancer therapy prior to admission, multivariate logistic regression was performed to identify factors associated with continuation of anticancer therapy. Factors yielding p values < 0.20 or considered to be clinically relevant were entered in the model and missing data (l.8%) were imputed by the nearest-neighbor method. Odds ratios (ORs) and their 95% confidence intervals (CI) were calculated for significant factors. One-year survival according to continuation of anticancer therapy after ICU discharge was evaluated using Kaplan–Meier survival function estimates. The impact of anticancer therapy on survival was assessed with the log-rank test.

The Karnofsky performance status was analyzed using a linear mixed model with anticancer therapy and times as fixed-effect factors, and the patient as random-effect factor. The linear mixed model was fitted with the restricted maximum-likelihood method. *Post hoc* tests of significance of the fixed-effect factor between pairs of conditions were performed with a likelihood ratio test.

Statistical analyses were performed using R version 3.5.2. and Matlab version 9.6.0.1150989 (R2019a).

Results

Figure 1 displays the study flowchart. Of the 91 patients included, 58 (64%) were admitted to the medical ICU and 33 (36%) were admitted to the neurological ICU.

Patient characteristics

The diagnosis of HGG was confirmed histologically in all patients and was based on examination of the surgical resection specimen for 33 (36%) patients or a biopsy specimen for 58 (64%) patients. The main characteristics of the 91 patients are displayed in Table 1. Tumor types were distributed as follows: 66 (73%) glioblastomas (grade IV), 15 (16%) anaplastic astrocytomas (grade III), and 10 (11%) anaplastic oligodendrogliomas (grade III). The cancer diagnosis was initiated or established during the ICU stay for 15 (16%) patients and was established prior to ICU admission for the remaining 76 (84%) patients; median time between cancer diagnosis and ICU admission was 6 (2–20) months. ICU and

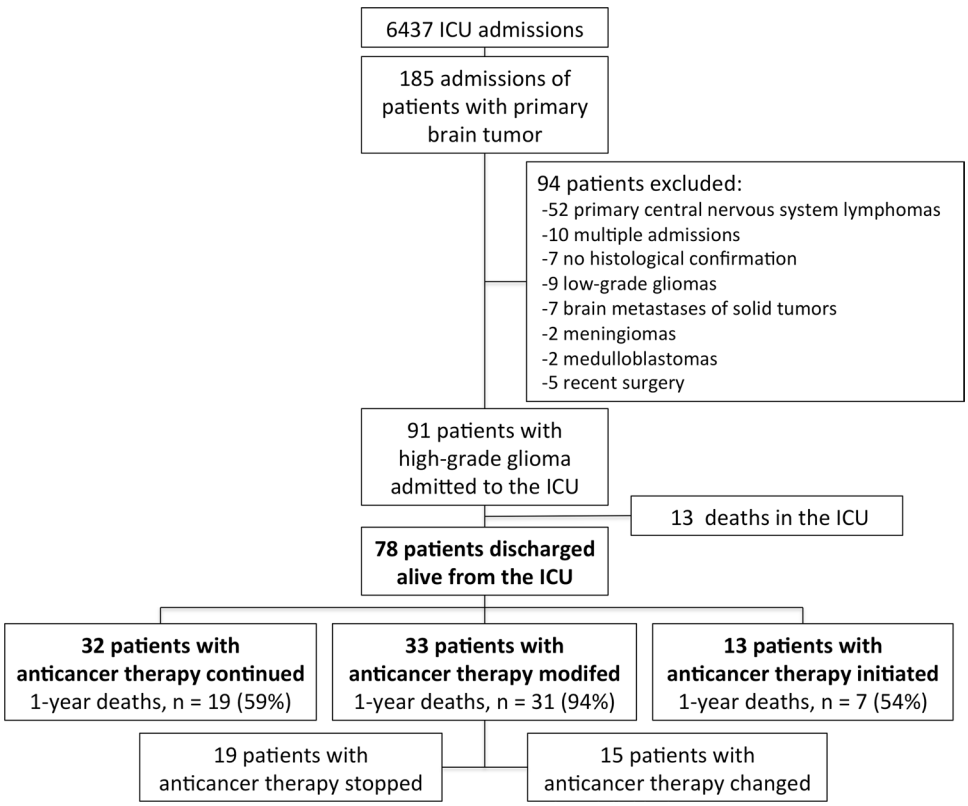

Fig. 1 Study flowchart

Table 1 Characteristics of the 91 patients at the time of intensive care unit (ICU) admission

Variables	
Age, *years*	57 (44–67)
Gender (male), *n (%)*	56 (62)
Comorbidities	
Chronic heart failure, *n* (%)	4 (4)
Chronic respiratory disease, *n* (%)	7 (8)
Charlson comorbidity index	3 (2–4)
Karnofsky performance status at admission, (%)	70 (60–85)
Disease status at admission	
Cancer progression, *n* (%)	48 (53)
Newly diagnosed, *n* (%)	15 (16)
Controlled, *n* (%)	28 (31)
Grade IV, *n* (%)	66 (73)
IDH1/2 mutation, *n* (%)	8 (17)
1p/19q codeletion, *n* (%)	2 (7)
Anticancer therapy received at admission	
Chemotherapy, *n* (%)	64 (70)
Radiotherapy, *n* (%)	55 (60)
Corticosteroid therapy, *n* (%)	60 (66)
Reason for admission	
Coma with seizures, *n* (%)	43 (47)
Coma without seizures, *n* (%)	15 (16)
Acute respiratory failure, *n* (%)	18 (20)
Shock, *n* (%)	7 (8)
Other, *n* (%)	8 (9)
Severity at admission	
SAPSII	32 (18–50)
SOFA	5 (3–7)
Physiological variables at admission	
Glasgow coma scale	8 (5–14)
Heart rate, *beats*/min	91 (78–107)
Systolic blood pressure, mmHg	120 (108–134)
Respiratory rate, cycle/minute	20 (16–24)
Temperature, °C	37 (36–37)
Laboratory variables at admission	
Leukocyte count, 10^9/L	7.8 (5.5–13.2)
Neutropenia, *n* (%)	5 (2)
Serum creatinine, µmol/L	69 (49–96)
Arterial blood gases	
pH	7.42 (7.36–7.47)
$PaCO_2$, mmHg	37 (31–42)
PaO_2/FiO_2	305 (224–387)
Life-sustaining intervention	
Mechanical ventilation, *n* (%)	45 (49)
Vasopressor, *n* (%)	17 (19)
Renal replacement therapy, *n* (%)	2 (2)

Continuous variables are expressed as median (interquartile interval) and categorical variables are expressed as numbers (%)

SAPS II Simplified Acute Physiology Score II; *SOFA* Sequential Organ Failure Assessment

hospital lengths of stay were 3 (2–7) and 16 (8–31) days, respectively. Seventy-eight patients (86%) were discharged alive from the ICU.

Anticancer therapy after ICU discharge

Among the 78 ICU survivors, anticancer therapy was continued in 32 (41%) patients, modified in 33 (42%) patients, and initiated in 13 (17%) patients. Table 2 shows the factors associated with continuation or modification of anticancer therapy after ICU discharge. On multivariate logistic regression, two factors were independently associated with continuation of anticancer therapy after ICU discharge: cancer progression at ICU admission (OR 0.09, 95% CI 0.02–0.35, $p = 0.001$) and use of corticosteroids (OR 0.07, 95% CI 0.01–0.35, $p = 0.002$) at ICU admission.

Mortality 1 year after ICU admission

The mortality rate 1 year after ICU discharge was 73% (57/78 patients). Table 3 depicts the factors associated with mortality 1 year after ICU admission identified by univariate analysis. On multivariate logistic regression analysis, two factors were independently associated with lower mortality 1 year after ICU admission: continuation of anticancer therapy after ICU discharge (OR 0.18, 95% CI 0.03–0.75, $p = 0.028$), and Karnofsky performance status at ICU admission (OR 0.90, 95% CI 0.85–0.95, $p < 0.001$).

Cumulative survival probability significantly differed between patients in whom anticancer therapy was continued, modified, or initiated (Fig. 2), with the greatest survival probability observed among patients in whom anticancer therapy was continued.

Changes in performance status after ICU discharge

Figure 3 shows changes in Karnofsky performance status from ICU admission to 1 year after ICU discharge in ICU survivors, according to management of anticancer therapy.

Karnofsky performance status was significantly different between the three anticancer therapy strategies and was the lowest in patients with anticancer therapy modified. Karnofsky performance status 1 year after ICU admission was > 60% in more than 50% of patients in whom anticancer therapy was initiated or continued.

Discussion

The main results of the study can be summarized as follows: in HGG patients discharged alive after an unplanned medical ICU stay (1), we observed a substantial proportion of survivors 1 year after ICU admission (more than one

Table 2 Univariate analysis: factors associated with the continuation or modification of anticancer therapy in intensive care unit survivors

Variables	ACT continued ($n=32$)	ACT modified ($n=33$)	*P*
Age, *years*	57 (50–65)	57 (44–66)	1.000
Gender (male), *n* (%)	20 (63)	22 (67)	0.725
Comorbidities			
Chronic heart failure, *n* (%)	0 (0)	4 (12)	0.114
Chronic respiratory disease, *n* (%)	1 (3)	2 (6)	1.000
Charlson comorbidity index	3 (2–4)	3 (2–4)	0.689
Karnofsky performance status at admission	70 (60–80)	70 (50–80)	0.349
Disease status at admission			
Cancer progression, *n* (%)	13 (41)	26 (79)	0.002
Grade IV, *n* (%)	20 (63)	28 (85)	0.040
IDH1/2 mutation, *n* (%)	3 (9)	2 (6)	0.661
1p/19q codeletion, *n* (%)	2 (6)	0 (0)	0.502
Anticancer therapy received at admission	25 (78)	31 (94)	0.082
Chemotherapy, *n* (%)	23 (72)	26 (79)	0.518
Radiotherapy, *n* (%)			
Corticosteroid therapy *n* (%)	19 (59)	30 (91)	0.004
Reason for admission			
Coma with seizures, *n* (%)	18 (56)	14 (42)	0.265
Coma without seizures, *n* (%)	3 (9)	5 (15)	0.709
Acute respiratory failure, *n* (%)	6 (19)	6 (18)	0.953
Shock, *n* (%)	2 (6)	4 (12)	0.672
Other, *n* (%)	3 (9)	4 (12)	1.000
Severity at admission			
SAPSII	39 (17–51)	29 (20–38)	0.423
SOFA	4 (3–6)	5 (3–7)	0.389
Physiological variables at admission			
Glasgow coma scale	9 (7–14)	8 (6–14)	0.796
Heart rate, *beats/min*	92 (80–107)	97 (81–105)	0.948
Systolic blood pressure, *mmHg*	116 (105–126)	130 (108–141)	0.056
Respiratory rate, *cycles/minute*	20 (17–22)	22 (19–24)	0.263
Temperature, °C	37 (36–37)	37 (37–38)	0.311
Laboratory variables at admission			
Leukocyte count, 10^9/L	9.2 (6.5–13,330)	7.1 (5.0–11.5)	0.042
Neutropenia, *n* (%)	0 (0)	2 (6)	0.492
Serum creatinine, µmol/L	67 (50–86)	70 (47–100)	0.778
Arterial blood gases			
pH	7.41 (7.35–7.47)	7.41 (7.37–7.44)	0.738
PaCO2, *mmHg*	39 (33–44)	36 (31–41)	0.299
PaO_2/FiO_2	331 (274–392)	300 (247–380)	0.487
Life-sustaining intervention			
Mechanical ventilation, *n* (%)	14 (44)	15 (45)	0.890
Vasopressor, *n* (%)	3 (9)	8 (24)	0.239
Renal replacement therapy, *n* (%)	1 (3)	0 (0)	0.492

Continuous variables are expressed as median (interquartile interval) and categorical variables are expressed as numbers (%]

SAPS II Simplified Acute Physiology Score II; *SOFA* Sequential Organ Failure Assessment,

quarter of patients) and most of these patients exhibited relatively favorable performance status even 1 year after ICU admission, (2) continuation of anticancer therapy was possible in almost 50% of patients and was strongly associated with cancer progression and use of corticosteroids at admission, and (3) continuation of anticancer therapy and

Table 3 Univariate analysis: factors associated with 1-year mortality in intensive care unit survivors

Variables	Survivors ($n=21$)	Non-survivors ($n=57$)	P
Age, *years*	50 (39–65)	56 (45–67)	0.207
Gender (male), *n* (%)	12 (57)	36 (63)	0.628
Comorbidities			
Chronic heart failure, *n* (%)	0 (0)	4 (7)	0.569
Chronic respiratory disease, *n* (%)	0 (0]	4 (7]	0.569
Charlson Comorbidity Index	2 (2–4]	3 (2–4]	0.128
Karnofsky performance status at admission	100 (70–100]	60 (50–80]	< 0.001
Disease status at admission			
Cancer progression, *n* (%)	6 (29)	33 (58)	0.022
Grade IV, *n* (%)	11 (52)	44 (77)	0.033
IDH 1/2 mutation, *n* (%)	4 (19)	4 (7)	0.201
1p/19q codeletion, *n* (%)	2 (10)	0 (0)	0.192
Anticancer therapy received at admission			
Chemotherapy, *n* (%)	13 (87)	43 (75)	0.239
Radiotherapy, *n* (%)	12 (80)	37 (65)	0.529
Corticosteroid therapy, *n* (%)	9 (60)	42 (74)	0.011
Reason for admission			
Coma with seizures, *n* (%)	13 (62)	28 (49)	0.316
Coma without seizures, *n* (%)	0 (0)	9 (16)	0.103
Acute respiratory failure, *n* (%)	3 (14)	11 (19)	0.748
Shock, *n* (%)	3 (14)	3 (5)	0.335
Other, *n* (%)	2 (10)	6 (11)	1.000
Severity at admission			
SAPSII	28 (17–50)	31 (17–49)	0.581
SOFA	4 (2–5)	5 (4–7)	0.036
Physiological variables at admission			
Glasgow coma scale	14 (7–15)	8 (6–13)	0.029
Heart rate, *beats/min*	89 (71–101)	92 (80–104)	0.517
Systolic blood pressure, *mmHg*	116 (102–122)	126 (108–140)	0.103
Respiratory rate, *cycles/minute*	20 (16–23)	20 (16–24)	0.883
Temperature, °C	37 (36–37)	37 (36–38)	0.865
Laboratory variables at admission			
Leukocyte count, $10^9/L$	9.3 (6.5–15.9)	7.6 (5.3–12.7)	0.073
Neutropenia, *n* (%)	1 (5)	1 (1)	0.412
Serum creatinine, *µmol/L*	65 (53–84)	70 (47–100)	0.959
Arterial blood gases			
pH	7.43 (7.39–7.48)	7.42 (7.36–7.46)	0.525
$PaCO_2$, *mmHg*	37 (35–44)	37 (31–41)	0.622
PaO_2/FiO_2, *mmHg*	342 (265–428)	302 (206–365)	0.107
Life-sustaining intervention			
Mechanical ventilation, *n* (%)	9 (43)	38 (54)	0.368
Vasopressor, *n* (%)	2 (10)	15 (21)	0.344
Renal replacement therapy, *n* (%)	0 (0)	2 (3)	1.000
Anticancer therapy after ICU discharge			
Continued, *n* (%)	12 (57)	20 (26)	0.009
Modified, *n* (%)	3 (14)	30 (53)	0.004
Initiated, *n* (%)	6 (29)	7 (12)	0.091

Continuous variables are expressed as median (interquartile interval) and categorical variables are expressed as numbers (%)

SAPS II Simplified Acute Physiology Score II; *SOFA* Sequential Organ Failure Assessment. *ICU* intensive care unit

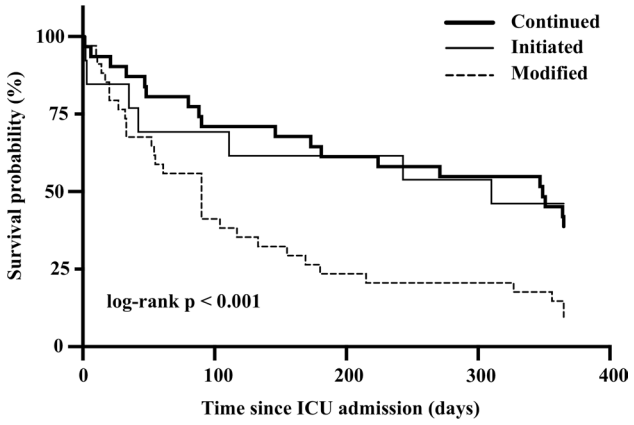

Fig. 2 One-year survival probability in high-grade glioma patients discharged alive from the intensive care unit (ICU) according to the management of anticancer therapy. Log-rank *p* value: Initiated vs. Modified, $p=0.022$, Initiated vs. Continued, $p=0.887$, Modified vs. Continued, $p=0.001$

Karnofsky performance status at admission were associated with higher 1-year survival rates.

To the best of our knowledge, this is the first report based on a homogeneous cohort of patients with HGG discharged alive after an ICU stay, focusing on 1-year mortality, health-related functional status, and management of anticancer therapy after ICU discharge.

First of all, the low ICU mortality rate observed in this study (14%) is consistent with recent findings, showing that ICU mortality is not higher in patients with primary malignant brain tumor than in patients with other types of solid cancer (1, 3–8) and patients without cancer [2, 25].

The survival rate of HGG patients 1 year after ICU admission observed in the present study was non-negligible (27%) and most patients still presented favorable performance status at 1 year (> 60%). Indeed, considering the median time between cancer diagnosis and ICU admission [6 (2–20) months] and considering the median survival of patients with HGG [14], the 27% survival after ICU admission observed in this study appears to be substantial and encouraging. Moreover, the survival rate 1 year after ICU admission was fairly similar to that observed in patients with other types of solid cancer [2, 11, 26–29] or hematologic malignancies [30–34]. Young age, limited comorbidities, and a high proportion of rapidly reversible causes, such as seizures, could explain this relatively high 1-year survival rate. The performance status observed over the study period is consistent with a previous report of primary malignant brain tumor patients admitted to the ICU [15]. In addition, our study shows that more than one-half of patients achieved a performance status, indicating that they were able to self-care at home (Karnofsky performance status ≥ 60%) [22]. This is a valuable observation when assessment of functional outcome is considered to be essential to evaluate the relevance of ICU admission or maintenance of intensive therapy.

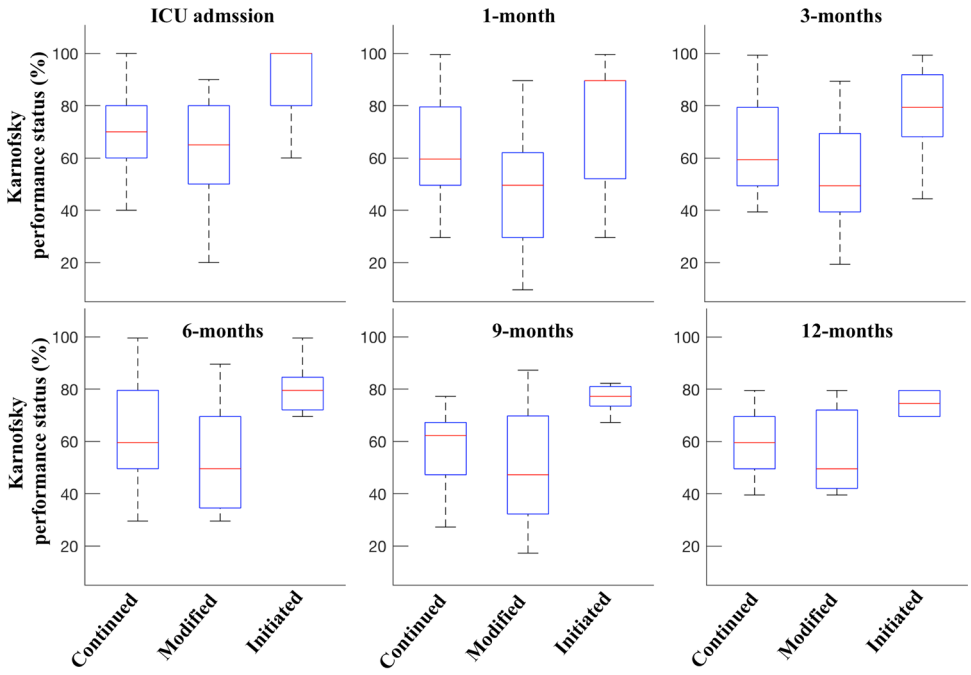

Fig. 3 Karnofsky performance status in intensive care unit (ICU) survivors at ICU admission and 1, 3, 6, 9, and 12 months after ICU admission according to the management of anticancer therapy. Anticancer therapy fixed-effect factor: $p<0.001$. Continued vs. Modified, $p=0.061$, Continued vs. Initiated, $p=0.150$, Modified vs. Initiated, $p=0.001$, Time fixed-effect factor: $p<0.001$, Patient random-effect factor: $p<0.001$

Anticancer therapy groups fixed effect: p<0.001
-Continued vs. Modified, p=0.061
-Continued vs. initiated, p=0.150
-Modified vs. initiated, p =0.001

To date, only a few studies have explored the impact of an ICU stay on anticancer therapy and the long-term outcome after ICU discharge [5–7, 26]. The rate of continuation of anticancer therapy observed in our study was similar to that reported in other studies [8–11]. Two factors, cancer progression and use of corticosteroids, were independently associated with failure to continue anticancer therapy in ICU survivors. While there is an obvious relationship between cancer progression and modification of anticancer therapy, the link between the use of corticosteroids and modification of anticancer therapy is less obvious and could be explained by the fact that corticosteroid prescription is generally driven by the presence of perilesional brain edema or neurological symptoms, which are both surrogates for disease activity [35]. Corticosteroid administration is a marker of poor disease control, often requiring modification of anticancer therapy. This finding is also in line with the fact that the cumulative corticosteroid dose delivered to patients with primary malignant brain tumor is associated with higher mortality [36] and decreased progression-free survival [37].

The strong influence of anticancer therapy management after ICU discharge on 1-year survival is also in line with the other reports concerning patients with solid cancer or hematologic malignancies, in whom 6-month [9, 11] and 1-year [10] survivals were higher in patients in whom anticancer therapy was continued after ICU discharge. Interestingly, we did not observe a higher survival rate in patients in whom anticancer therapy was initiated for a newly diagnosed cancer, which is consistent with the previous reports on patients admitted to the ICU with a newly diagnosed cancer, supporting the idea that critically ill patients with underlying undiagnosed cancer are likely to present locally advanced or metastatic disease with poor medium- [29] and long-term prognosis [27]. In these reports, Karnofsky performance status at ICU admission was also independently associated with long-term mortality [10, 11].

The present study has several limitations. First, it was a retrospective study, which implies a potential bias in patient selection or data collection. However, data were extracted from a prospectively managed database and the rarity of the disease remains a major obstacle to prospective studies, even with a multicenter design. Second, the relevance of Karnofsky performance status as a health-related functional endpoint in this very specific population could be questioned. It is possible that other decisive aspects of quality of life, psychological states, and cognitive function, all likely to be impaired in HGG [14, 15], were ignored. Third, while we report data for patients admitted to the ICU, we did not report the proportion of HGG patients for whom ICU admission was refused during the study period, or the policies or criteria that motivated these refusals, and it is possible that patients with the poorest prognosis were, therefore, not admitted to the ICU and, thus, not included in this analysis. Finally, because molecular testing has been systematically performed only since 2013, whereas the study period started in 2009, this study comprises many missing data and consequently failed to demonstrate any association between molecular testing and prognosis [38].

In conclusion, we report that a high proportion of HGG patients who survived an ICU stay may benefit from continuation of anticancer therapy after discharge, with preserved performance status, and can, therefore, expect a non-negligible survival 1 year after ICU admission. Simple factors, which can be easily identified before ICU admission, such as cancer progression, use of corticosteroids, or Karnofsky performance status at admission, are strongly associated with outcomes. If decisions concerning life-sustaining interventions are no longer considered to be futile in patients with active cancer, even metastatic cancer, a similar attitude could also be applied to HGG patients, who have probably been unreasonably denied ICU admission for many years. These results will certainly contribute to refine ICU admission policies which, in every case, should take into account the neuro-oncologists' experience and the patient's willingness.

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Compliance with ethical standards

Conflicts of interest Thomas Similowski reports personal fees from ADEP Assistance, AstraZeneca France, Boerhinger Ingelheim France, Chiesi France, GSK France, Lungpacer Inc., Novartis France, TEVA France, outside the submitted work; In addition, Dr. Similowski has a patent titled "brain–ventilator interface" licensed to Air Liquide Medical Systems and MyBrainTechnology, a patent for a "protection device for intubation" pending, and a patent for a "non-contact thoracic movement imaging system» pending. Alexandre Demoule reports personal fees from Medtronic, grants, personal fees, and non-financial support from Philips, personal fees from Baxter, personal fees from Hamilton, personal fees, and non-financial support from Fisher & Paykel, grants from French Ministry of Health, personal fees from Getinge, grants and personal fees from Respinor, and grants and non-financial support from Lungpacer, outside the submitted work. Martin Dres received personal fees and travel expenses from Lungpacer outside the submitted work. Nicolas Weiss has signed research contracts with Eumedica, BMS, MedDay pharmaceuticals; he has also received personal fees

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Ethics approval The study was approved by the French Intensive Care Society Institutional Review Board (CE SRLF 20-15) and information was given to the patients or their relatives.

Availability of data and material Our data are available to ensure transparency.

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