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ORIGINAL ARTICLE

When the practice does not meet the theory: results from an Italian survey on the clinical and pathway management of inpatients with decompressive craniectomy or cranioplasty admitted to rehabilitation

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ABSTRACT

BACKGROUND: Cranioplasty (CP) is supposed to improve the functional outcome of severe acquired brain injury (sABI) patients with decompressive craniectomy (DC). However, ongoing controversies exist regarding its indications, optimum materials, timing, complications, and relationships with hydrocephalus (HC). For these reasons, an International Consensus Conference (ICC) on CP in traumatic brain injury (TBI) was held in June 2018 to issue some recommendations.
AIM: The aims of this study were: to investigate cross-sectionally before the ICC the prevalence of DC/CP in sABI inpatients admitted to neurorehabilitation units in Italy; to assess the perception of Italian clinicians working in the sABI neurorehabilitation settings on the management of inpatients with DC/CP during their rehabilitation stay.
DESIGN: Cross-sectional.
SETTING AND POPULATION: Physiatrists or neurologists working in 38 Italian rehabilitation centers involved in the care of sABI, giving a pooled sample of 599 inpatients.
METHODS: Survey questionnaire consisting of 21 closed-ended questions with multiple-choice answers. Sixteen questions regarded the respondents' opinions and experiences regarding the clinical and management aspects of patients. Survey data were collected via e-mail between April and May 2018.
RESULTS: About 1/3 of the 599 inpatients had either a DC (18.9%) or a CP (13.5%). TBI and cerebral hemorrhage were strongly associated with DC/CP, although the association was much stronger for TBI. Significant discrepancies were uncovered between some of the recommendations of the ICC and the corresponding perceptions of the respondents, especially regarding the clinical management of patients (*i.e.*, CP timing). Clear guidelines were perceived as the most crucial factor in improving clinical pathways.

CONCLUSIONS: Early collaboration between the neurosurgical and the neurorehabilitation teams is crucial to optimize all clinical and organizational factors, which could expedite CP and minimize the risk of complications, such as infections and HC, to ensure the best possible outcome for DC patients, regardless of the etiology of the sABI.
CLINICAL REHABILITATION IMPACT: There may be different attitudes and perceptions, if not controversies, between neurorehabilitation physicians and neurosurgeons regarding the optimal clinical and care pathway management of patients with DC/CP in Italy. Therefore, an Italian Consensus Conference involving all stakeholders on the clinical and management pathways of DC/CP patients admitted to neurorehabilitation is advocated.

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KEY WORDS: Decompressive craniectomy; Rehabilitation; Brain injuries, traumatic; Surveys and questionnaires; Cranioplasty.

Decompressive craniectomy (DC) has been increasingly performed in recent years to manage refractory intracranial hypertension due to severe Acquired Brain Injury (sABI).[1-3] In particular, DC is often performed in severe traumatic brain injury (TBI),[2, 4] massive intracerebral (ICH)[4, 5] and subarachnoid hemorrhages (SAH),[4] malignant edema due to middle cerebral artery ischemia,[4] intracranial infections and tumors.[6]

Several international multicenter studies, such as DECRA and RESCUE-ICP, showed the efficacy of DC in reducing mortality of TBI in the acute phase, although there is an increase in disability.[7, 8] Indeed, DC is not exempt from delayed complications, such as the development of the so-called syndrome of the trephined (SoT), also known as sinking skin flap syndrome (SSFS).[9] This condition has been recently defined as a syndrome of progressive neurological deterioration or failure to progress, characteristically occurring weeks or months after DC.[9] The symptomatology of SoT depends upon the initial clinical picture of the patient. One frequent sign is the worsening of the neurological status in seated or upright positions, followed by improvement by recumbing in a supine position.[9] However, in most severe cases, prolonged decompression may be associated with severe complications such as protracted disorders of consciousness,[10] hydrocephalus (HC),[11, 12] and recurrent infections.[13, 14]

For the above reasons, DC should be considered a two-stage procedure,[3] where the second stage is represented by cranioplasty (CP). CP is a restorative neurosurgical procedure in which the DC skull defect is reconstructed to improve esthesis, restore adequate cerebral protection, cerebrospinal fluid circulation and cerebral blood flow, and facilitate neurological recovery.[15] Although CP is not exempt from complications,[15] several studies have demonstrated the potential for significant improvement of neurological status following CP,[9, 16] especially in patients with TBI.[17, 18] Recently, Sveikata *et al.* suggested that SoT symptoms' improvement may occur as early as four days after CP,[9] although delaying the intervention may negatively influence the extent of neurological improvement.[9, 16, 19, 20] However, the evidence regarding the relationship between functional outcome and CP timing is controversial.[11, 21] Other controversial issues regard, for instance, CP materials and the relationship between HC management and DC or CP.

These controversies, together with the lack of clear guidelines on CP, led the Neurotrauma Committee of the World Federations of Neurosurgical Societies in 2018 to promote an international consensus conference (ICC) on CP in TBI with the specific aim of producing recommendations and consensus statements addressing all the controversial issues regarding CP. The ICC was held in Naples (Italy) in June 2018 during the International Conference on Recent Advance in Neurotrauma (ICRAN; https://wfns.org/events/16/wfns-committee-events/110/icran-2018), and its recommendations have been recently published.[22] In addition, as preparatory work before the consensus event, the invited representatives of the Italian Society of Neurorehabilitation (SIRN, www.SIRN.net) launched a survey amongst clinicians working within the neurorehabilitation ward settings across Italy.

Thus, this paper reports on the results of this survey, whose specific aims were: 1) to investigate cross-sectionally the prevalence of DC and CP in patients with sABI admitted to neurorehabilitation units in Italy; 2) to assess the perception of Italian clinicians working in the sABI neurorehabilitation settings on the management of inpatients with DC and CP during their rehabilitation stay.

Materials and methods

Design and participants

The study was devised as a cross-sectional survey by the Special Interest Group on sABI and DoC of the SIRN

(sABI&DoC-SIG). The inclusion criterion for completing the questionnaire was being a neurorehabilitation physician (physiatrist or neurologist) working in a neurorehabilitation ward admitting adult inpatients with sABI in the postacute phase. There were no formal exclusion criteria, although participants working in the same center were invited to respond to the questionnaire collegially to collect only one questionnaire per center.

Each center provided only anonymous and aggregated data within the study, with no direct patient interview. By participating in the survey, each physician provided consent to participation. The study was conducted according to the principles outlined in the Helsinki Declaration.

Survey questionnaire

Four SIRN sABI&DoC-SIG members (F.L.P., R.F., A.D.T., and A.E.) collegially discussed and devised the item set on a digital cloud platform, after considering current literature on DC/CP (DC still in place or CP already performed) in patients with sABI. The criteria followed for developing the items were as follows: 1) the item content had to be of high clinical relevance for the respondents; 2) questions had to be appropriate to the expected level of clinical knowledge and skills of the respondents; 3) the questionnaire had to impose the least possible administrative burden, requiring it to be completed in one sitting within 10 minutes; 4) the response format had to prevent biases, such as acquiescence[23] and extreme response bias.[24] Furthermore, to avoid the neutral responding bias, questions had to be based on an even number of response categories without a middle response option stating a "neutral" response. However, we allowed a "don't know" option.

Thus, following these guidelines, a final set of 21 closed-ended questions with multiple-choice answers was developed. The resulting item set could be divided into two sections. The first section included sixteen questions focusing on the respondent's opinions and experience in two main areas related to the management of patients with DC/CP: 1) clinical aspects, such as recovery following CP, complications such as SSFS and HC, CP materials (N.=9: Q1-Q3, Q6, Q8-Q12); 2) organizational or procedural aspects such as neurosurgical decisional pathways and timing, CP intervention timing, ventriculoperitoneal shunting (VPS) for HC in relationship to CP intervention (N.=7: Q4-Q5, Q7, Q13-Q16).

The second section included five questions (Q17-Q21) focusing on epidemiological information. In particular, each respondent was requested to provide the number of inpatients within the respondent's facility on the survey day for the following five groups: sABI, DC, DC+VPS, DC scheduled for CP intervention (DC-WL), and CP. Furthermore, they were requested to provide the etiology of the lesion (TBI; hemorrhage; ischemic; anoxic/other) and the time since injury (<1 month; 1-3 months; >3 months). As the epidemiological section was potentially more difficult to answer (as some data might have required additional information not immediately available), it was located purposefully at the end of the questionnaire to prevent question order bias.[25]

Survey dissemination procedure

Before dissemination, each survey developer (F.L.P., R.F., A.D.T., and A.E.) asked a working colleague to compile the survey and give feedback to refine the questionnaire. This pilot phase showed that the questionnaire was easy to understand and needed only 5 to 10 minutes to be completed.

The survey was sent by e-mail to the mailing list of the SIRN sABI&DoC-SIG members (including 88 rehabilitation physicians) and seven other colleagues known to work in sABI neurorehabilitation. The invitations were sent on 17th April 2018. After that, three reminders were sent to solicit responses. Thus, data were received at a dedicated e-mail address until the closure of data collection on 8th May 2018.

Data analysis

The following analyses were performed:

- descriptive statistics for the epidemiological survey: respondents. We described the respondents using simple frequencies, characterizing their geographical distribution and rehabilitation setting (*i.e.*, intensive rehabilitation, C56, *vs*. highly specialized neurorehabilitation for sABI, C75);
- descriptive statistics for the epidemiological survey: patients. We described the inpatient population using simple frequencies for the five groups (with sABI, DC, DC+VPS, DC-WL, CP) and their characteristics regarding time since injury and etiology of sABI. We also extrapolated the frequencies of patients with DC not scheduled for CP (DC-nWL) from the available data;
- descriptive statistics for the opinion survey. We calculated simple frequency distributions of each response for each question. We collapsed responses within a given item to maximize the information where possible;
- subgroup analysis by rehabilitation setting. We calculated descriptive statistics for the epidemiological and sur-

vey section separately for each rehabilitation setting subgroup. χ^2 statistics were employed to test the significance of the association between rehabilitation settings and other variables, such as the prevalence of DC, CP, DC+VPS, time since injury, and etiology. We also tested the significance of the association between the respondent's setting and the degree of self-reported sufficient experience to answer each question;

• analysis of the discrepancies between the recommendations of the ICC and the corresponding items of the opinion survey. We attempted to match post hoc the published ICRAN ICC statements with the survey's questions related to the same concept. When a statement and a question could be conceptually matched, the survey question was then transformed into the corresponding statement employing the same response options used within the ICC ("agree" *vs*. "disagree") by collapsing the response categories. For instance, "*In your opinion, how important is CP from a neuro-rehabilitation point of view?*" (Q1) was transformed into the following statement: "*CP is important from a neurorehabilitation point of view*". As shown in Supplementary Digital Material 1 (Supplementary Table I), the collapsed response options of the original question ("important" *vs*. "non-important") were transformed into "agree" *vs*. not "agree". The raw data were then converted into percentages to allow mathematical comparison, thus enabling the construction of ad-hoc 2x2 tables. Therefore, it was possible to associate conceptually similar statements with the degree of agreement on them expressed by the respondents (*i.e.*, the ICC expert's opinion *vs*. the Italian neurorehabilitation physicians' perception) by the mean of a chi-square test for association. In particular, a significant χ^2 would be expected in case of substantial disagreement between the recommended and the actual practice.

We also reported the effect sizes (ES) in terms of phi coefficient (φ) or Cramer's v (φ_c) for 2x2 or 2x2+n tables, respectively, for all significant χ^2 tests.

Data availability statement

The raw data supporting the conclusions of this article are available for download at Zenodo.org (according to the license Creative Commons Attribution 4.0 International) from the following link: [https://zenodo.org/record/7769628].

Results

Descriptive statistics for the epidemiological survey: respondents

As shown in Table I, 38 centers participated in the study for a cumulative sample of 599 patients with sABI. Each center contributed with a median number of 13 cases (range: 1-55).

Almost two-thirds of the responding centers were highly specialized in neurorehabilitation of sABI (C75), whereas the remaining one-third were intensive rehabilitation centers (C56). Twelve centers were public health institutions, whereas the remaining 68% of the centers were private. Twenty-four centers were located in Northern Italy, 5 in Center Italy, and 8 in Southern and Insular Italy, corre-

TABLE I.—*Epidemiological survey: general descriptive statistics.*

	Centers	Patients sample		DC sample		CP sample		DC/CP sample	
	N.	N.	%	N.	%	N.	%	N.	%
All respondents	38	599	-	113	18.9%	81	13.5%	194	32.4%
Cases by center									
Range		[1, 55]		[0, 13]		[0, 10]		[0, 21]	
Mean		15.8		3		2.1		5.1	
SD		13.1		3.3		2.4		5.0	
Median		13		2		2		3	
Interpercentile range [10P, 90P]		[6, 32]		[0, 73]		[0, 53]		[1, 9.3]	
Neurorehabilitation setting									
C75	24	427	71.3%	81	13.5%	57	9.5%	138	23.0%
C56	14	172	28.7%	32	5.3%	24	4.0%	56	11.2%
Macro-geographical areas									
Northern Italy	24	318	53.1%	65	20.4%	48	15.1%	113	35.5%
Central Italy	5	111	18.5%	19	17.1%	14	12.6%	33	29.7%
Southern and Insular Italy	9	170	28.4%	29	17.1%	19	11.2%	48	28.2%

DC: patients with decompressive craniectomy (*i.e.*, with an "open box"); CP: patients with previous DC for whom cranioplasty was already performed (*i.e.*, with a "closed box"); DC/CP: the total number of patients with open or closed box; C75: highly specialized neurorehabilitation for sABI; C56: intensive rehabilitation.

TABLE II.—*Epidemiological survey: descriptive statistics by time since lesion and etiology.*

	N.	% out of the total sample (N.=599)	% out of the DC subsample (N.=113)	% out of the CP subsample (N.=81)	% out of the DC/CP subsample (N.=194)
Whole sample	599	100%			
Timing lesion-survey (months)					
<1 month	82	13.7%			
1-3 months	217	36.2%			
>3 months	265	44.2%			
Missing	35	5.8%			
Etiology					
Cerebral hemorrhage	235	39.2%			
Traumatic brain injury	172	28.7%			
Ischemic brain injury / other	103	17.2%			
Anoxic brain injury	79	13.2%			
Missing	10	1.7%			
DC subsample	113	18.9%	100%		58.2%
Time since lesion (months)					
<1 month	19	3.2%	16.8%		9.8%
1-3 months	36	6.0%	31.9%		18.6%
>3 months	51	8.5%	45.1%		26.9%
Missing	7	1.2%	6.2%		3.6%
Etiology					
Traumatic brain injury	37	6.2%	32.7%		19.1%
Cerebral hemorrhage	57	9.5%	50.4%		29.4%
Anoxic brain injury	0	-	-		-
Ischemic brain injury/other	14	2.3%	12.4%		72.2%
Missing	5	0.8%	4.4%		26%
DC+VPS subsample	18	3.0%	15.9%		9.3%
Time since lesion (months)					
<1 month	1	0.2%	0.9%		0.5%
1-3 months	8	1.3%	7.1%		4.1%
>3 months	7	1.2%	6.2%		3.6%
Missing	2	0.3%	1.8%		1.0%
Etiology					
Traumatic brain injury	6	1.0%	5.3%		3.1%
Cerebral hemorrhage	10	1.7%	8.8%		5.2%
Anoxic brain injury	0	-	-		-
Ischemic brain injury / other	1	0.2%	0.9%		0.5%
Missing	1	0.2%	0.9%		0.5%
DC-WL	59	9.8%	52.2%		30.4%
Time since lesion (months)					
<1 month	1	0.2%	0.9%		0.5%
1-3 months	27	4.5%	23.9%		13.9%
>3 months	27	4.5%	23.9%		13.9%
Missing	4	0.7%	3.5%		2.1%
Etiology					
Traumatic brain injury	13	2.2%	11.5%		6.7%
Cerebral hemorrhage	28	4.7%	24.8%		14.4%
Anoxic brain injury	-	-	-		-
Ischemic brain injury / other	9	1.5%	8.0%		4.6%
Missing	9	1.5%	8.0%		4.6%
DC-nWL	54	9.0%	47.8.2%		27.8%
Time since lesion (months)					
<1 month	18	3.0%	15.9%		9.3%
1-3 months	9	1.5%	7.9%		4.6%
>3 months	24	4.0%	21.2%		12.4%
Missing	3	0.5%	2.7%		1.5%
Etiology					
Traumatic brain injury	24	4.0%	21.2%		12.4%
Cerebral hemorrhage	29	4.8%	25.7%		14.9%

(To be continued)

TABLE II.—*Epidemiological survey: descriptive statistics by time since lesion and etiology (continues).*

	N.	% out of the total sample (N.=599)	% out of the DC subsample (N.=113)	% out of the CP subsample (N.=81)	% out of the DC/CP subsample (N.=194)
Anoxic brain injury	-	-	-		-
Ischemic brain injury / other	5	0.8%	4.4%		2.6%
Missing	1	0.2%	0.9%		0.5%
CP subsample	81	13.5%		100%	41.8%
Time since lesion (months)					
<1 month	5	0.8%		6.2%	2.6%
1-3 months	23	3.8%		28.4%	11.9%
>3 months	53	8.8%		65.4%	27.3%
Missing	0	-		-	-
Etiology					
Cerebral hemorrhage	43	7.2%		53.1%	22.2%
Traumatic brain injury	36	6.0%		44.4%	18.6%
Ischemic brain injury / other	2	0.3%		2.5%	1.0%
Anoxic brain injury	0	-		-	-
Missing	0	-		-	-
DC+CP subsample	194	32.4%			100%
Time since lesion (months)					
<1 month	24	4%			12.4%
1-3 months	59	9.8%			30.4%
>3 months	104	17.4%			53.6%
Missing	7	1.2%			3.6%
Etiology					
Traumatic brain injury	73	12.2%			37.6%
Cerebral hemorrhage	100	16.7%			51.5%
Anoxic brain injury	-	-			-
Ischemic brain injury / other	16	2.7%			8.2%
Missing	5	0.8%			2.6%

In its two first columns, this table shows the absolute number and percentage of patients out of the total sample for the various subsamples (DC, DC+VPS, DC-WL, DC NOT-WL, CP, DC/CP). Within the subsequent three columns, the percentages are calculated relatively to the number of patients within the pertaining subsample. Thus, for instance, the 18 patients with DC+VPS, represent only 3% of the total sample (N.=599, second column), 15.9% of all patients with DC (N.=113, third column), and 9.3% of the entire subgroup of DC/CP (N.=194, fifth column).
DC: patients with decompressive craniectomy (*i.e.*: with an "open box"); CP: patients with previous DC for whom cranioplasty was already performed (*i.e.*: with a "closed box"); DC/CP: patients with either a DC or a CP (*i.e.*: with an open or a closed box); DC+VPS: patients with a decompressive craniectomy and a ventriculo-peritoneal shunt performed for hydrocephalus; DC-WL: patients with a DC already scheduled for CP intervention; DC-nWL: patients with DC not yet scheduled for CP.

sponding to a patient distribution of 43.1%, 18.5%, and 28.4% of the total patient sample.

Descriptive statistics for the epidemiological survey: patients

A number of 113 and 81 patients within the patient sample had either a DC (18.9%) or a CP (13.5%), respectively. Overall, the patients with DC/CP were almost one-third of the whole sample (32.4%). Each center contributed with a median of 3 patients with DC/CP (average 5.1; range: 0-21). About seven patients with sABI out of 10 were admitted to C75 facilities, which admitted about seventy percent of DC/CP patients of the whole sample. Almost one patient out of four admitted to a C75 facility had a DC/CP, whereas the ratio was one in ten for C56 facilities. There was no statistically significant association between rehabilitation setting and prevalence of DC ($\chi^2=2.8_1$, P=0.092), CP ($\chi^2=0.2_1$, P=0.889), and DC/CP ($\chi^2=0.5_1$, P=0.463), as well as between geographic area and prevalence of DC/CP ($\chi^2=0.109_2$; P=0.947).

On the day of the survey, 265 cases (44.2%) had been inpatients for >3 months after the injury, 217 (36.2%) for 1-3 months, and some patients (N.=82; 13.7%) for <1 month (Table II). Within the sample, 28.7% of the cases (N.=172) had a TBI, whereas most patients (N.=235, 39.2%) had suffered from a cerebral hemorrhage. In addition, 13.2% (N.=79) and 17.2% (N.=103) of cases had suffered from anoxic and ischemic brain injury, respectively. Within the DC subsample, 18 inpatients (15.9%) had a VPS, and about half (59; 52.2%) were already scheduled for CP intervention.

We found a statistically significant association between the presence of DC/CP and the etiology of brain injury ($\chi^2=25.638_2$; P<0.000; $\varphi_c=0.224$, small ES). In particular, either a diagnosis of TBI or cerebral hemorrhage was

associated with the presence of DC/CP (TBI: $\chi^2=11.1_1$, P<0.0008, φ=0.254, small ES; Hemorrhage: $\chi^2=18.1_1$, P<0.0000, φ=0.279, small ES). In addition, there was a significant negative association between the presence of DC/CP and cerebral ischemia ($\chi^2=16.1_1$, P<0.0000, φ=0.396, medium ES) compared to other etiologies. We found no significant association between being or not being scheduled for CP intervention and the etiology of sABI ($\chi^2=2.8_1$, P=0.093).

Time from injury was significantly higher in patients with DC/CP than those without DC/CP ($\chi^2=8.363_1$; P=0.004; φ=0.167, small ES). In particular, within the DC/CP subsample, the proportion of inpatients for >3 months since injury was higher (55.6%) than in the total sample (42.7%). Overall, there were 51 DC inpatients (45.1%) awaiting for >3 months a CP, and only 27 (51%) were already scheduled for CP intervention. After extrapolating data, we found a significant association between time since lesion and being or not scheduled for CP ($\chi^2=15.7_1$; P<0.000; φ=0.661, large ES). In particular, as expected, the number of inpatients 1-3 months from injury was much higher in the DC-WL (N.=27) than in the DC-nWL group (N.=9). Still, the number of inpatients >3 months from injury was almost equal in the DC-WL and the DC-nWL groups (N.=27 and N.=24).

As shown in Table III, the comparison of our epidemiological data with the literature[4-6, 9, 26] showed that the prevalence of DC secondary to TBI (38.6%) was close to the values reported within the literature (median prevalence: 37.3%). On the other hand, the prevalence of DC secondary to hemorrhagic events (both SAH and ICH) was much higher (52.9%) than that reported in previous studies (median value 32.0%). Finally, the prevalence of DC secondary to ischemic stroke or other causes (8.5%) was much lower than expected based on the literature data (median prevalence: 39.7%).

Descriptive statistics for the opinion survey

As shown in Supplementary Digital Material 1 (Supplementary Table I), most respondents (80.9%) reported frequent cognitive and/or motor improvement following CP (Q2). However, half of the respondents (50.0%) had rarely observed cognitive or motor worsening due to SSFS (Q3).

Only 15.8% of respondents indicated that VPS was usually performed after CP (Q7). Furthermore, 31.3% of the respondents declared that they had seen complications occurring when VPS had been performed before or during a CP intervention, whereas an equal number had not (Q8). Interestingly, though, most respondents (36.8%) reported having insufficient experience.

More than one-third of the respondents (39.5%) reported that colonization with multidrug resistant organisms (MDRO) was frequently a contraindication to performing CP (Q9). On the other hand, the majority of respondents (81.6%) indicated that CP infection was a rare complication (Q10), and 28.9% of them reported that, in such cases, they felt they had no sufficient experience regarding the exact timing for a new CP intervention (Q12).

Around half of the respondents (47.4%) reported that the material used for CP was mostly autologous bone (Q6). However, only a minority of them (21.1%) reported the occurrence of delayed (beyond two years) bone resorption (Q11). About one respondent in four (27.6%) had seen delayed bone resorption of CP, although nine respondents (23.7%) indicated that they had no experience.

Although 81.6% of centers reported the availability of referral neurosurgeons (Q14), only 42.1% of the respondents reported the complete availability of the neurosurgical referral center to perform CP on patients operated on by other neurosurgical teams during the acute phase (Q15). In addition, only 52.6% of centers reported being satisfied with the postoperative neurosurgical follow-up, while 13.2% of respondents reported a total lack of follow-

TABLE III.—*Epidemiological survey: comparison of etiology prevalence for DC/CP between literature data and study data.*

	Ziai 2003,[26] N.=17		Kim 2009,[5] N.=75		Tagliaferri 2012,[4] N.=501		Goedemans 2017,[6] N.=204		Sveikata 2022,[9] N.=40		Whole sample, N.=837		La Porta 2022, N.=189	
	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%	N.	%
a. ICH	2	11.8%	24	32.0%	110	22.0%	44	21.6%	8	20.0%	188	22.5%		
b. aSAH	0	0.0%	0	0.0%	76	15.2%	29	14.2%	1	2.5%	106	12.7%		
c. TBI	3	17.6%	28	37.3%	284	56.7%	50	24.5%	15	37.5%	380	45.4%		
d. Ischemia	12	70.6%	23	30.7%	31	6.2%	57	27.9%	13	32.5%	136	16.2%		
e. Other	0	0.0%	0	0.0%		0.0%	24	11.8%	3	7.5%	27	3.2%		
a+b.Cerebral haemorrhage	2	11.8%	24	32.0%	186	37.1%	73	35.8%	9	22.5%	294	35.1%	100	52.9%
c. Traumatic brain injury	3	17.6%	28	37.3%	284	56.7%	50	24.5%	15	37.5%	380	45.4%	73	38.6%
d+e. Other	12	70.6%	23	30.7%	31	6.2%	81	39.7%	16	40.0%	163	19.5%	16	8.5%

ICH: intracerebral hemorrhage; aSAH: aneurysmal subaracnoidal hemorrhage; TBI: traumatic brain injury.

up (Q13). Overall, the majority of respondents (76.3% and 81.6%) reported, respectively, long waiting times for transfer to Neurosurgery (Q4) and a long duration of the whole clinical pathway (Q5).

Although the totality of respondents indicated that CP was an important procedure from a neurorehabilitation point of view (Q1), more than half of them (57.9%) reported the need for clear guidelines for CP as the single factor which, per se, could impact the outcome of the DC/CP patients (Q16) positively.

Subgroup analysis by rehabilitation setting

Within the epidemiological section of the survey, we found no significant association between rehabilitation settings (C75 *vs*. C56) and prevalence of DC/CP, DC or CP alone, DC+VPS, or timing of admission to inpatient rehabilitation. Regarding etiology, we found a significant association only between general inpatient rehabilitation setting (C56) and anoxic etiology ($\chi^2=5.0_1$, P=0.025, φ=0.162, small ES).

A χ^2 test indicated a significant association between the respondent's setting and the degree of self-reported expertise. In particular, there was a higher frequency of self-reported "not sufficient experience" within the C56 group compared to the C75 respondents considering all questions (χ^2 19.0_1; P=0.000; φ=0.237, small ES). Regarding the specific questions, we found no association between the respondents' setting and the occurrence of the "insufficient experience to answer" response option to questions Q13 (timing of reintervention after CP infection), Q11 (delayed bone resorption), and Q3 (occurrence of SSFS). However, regarding question Q18 (timing of VPS in patients with DC), we found a significant association between respondents' setting and the "insufficient experience to answer" option ($\chi^2=4.91$; P=0.026, φ=0.360, medium ES), as the prevalence of the latter option response was much higher within the C56 than C75.

Discrepancies between the recommendations of the ICC and the corresponding items of the opinion survey

We could conceptually match only four ICC statements with seven survey questions (Table IV). We found no statistically significant disagreement on two statements regarding the need to perform CP and the possible neurological improvement associated with CP. On the other side, we found some substantially significant disagreements with large ES (φ ranging between 0.847 and 0.894) between the theoretical recommendation (*i.e.*, the need to expedite CP, especially in case of neurological deterioration: $\chi^2=79.9_1$; P<0.000; φ=0.894) and the actual perception of the neurorehabilitation physicians regarding the whole earliness of the CP neurosurgical pathway ($\chi^2=70.3_1$; P<0.000; φ=0.847). Furthermore, we also found a strong disagreement with a large ES regarding the statement that colonization with MDRO should not be a contraindication to perform CP ($\chi^2=29.9_1$; P<0.000; φ=0.562). Finally, we found a strong disagreement with a large ES between the consensus conference statement indicating the opportunity to perform VPS after CP in the case of HC and the perception that VPS is not performed only after CP ($\chi^2=86.4_1$; P<0.000; φ=1.195).

Discussion

Within this manuscript, we reported on a survey launched by the SIRN sABI&DoC-SIG before the International Con-

TABLE IV.—*Association between neurosurgical practices (theoretical, as suggested by the consensus conference, and practical, as viewed by neurorehabilitation physicians) and clinical and management modalities for DC/CP patients.*

Neurosurgical practices (theoretical *vs*. practical, as viewed from the perspective of neuro-rehabilitation physicians)			Agreement on clinical and management modalities		Chi-sq_{df}	P	Phi	Effect size
			Agree	Do not agree				
Consensus	1.3	An effort should be made to perform CP	100	0	NC	-	-	-
Survey	Q1	To perform CP is important	100	0				
Consensus	3.1	CP may improve neurological function	84.6	15.4	1.5_1	0.226	-	-
Survey	Q2	I have seen neurological improvement following CP	73.7	21.0				
Consensus	3.1	Earlier CP may enhance neurological improvement	81.6	18.4	70.3_1	0.000	0.847	Large
Survey	Q5	Timing of the entire path is short	21.6	76.3				
Consensus	3.5	Expedite CP in case of deterioration	81.6	18.4	79.9_1	0.000	0.894	Large
Survey	Q4	Timing of transfer to neurosurgery for CP is rapid	18.4	81.6				
Consensus	3.8	Skin colonization should not be a contraindication for CP	92.0	8.0	29.2_1	0.000	0.562	Large
Survey	Q9	MDRO colonization is not a contraindication for CP	39.5	55.3				
Consensus	4.4	Performing VPS after CP should be considered in case of hydrocephalus	95.8	4.2	86.4_1	0.000	1.195	Large
Survey	Q7	VPS is performed only after CP	15.8	44.7				

sensus Meeting on Post-Traumatic Cranioplasty, held in Naples in June 2018.[22] The survey was conducted amongst neurorehabilitation physicians working in the sABI setting on the epidemiology and their perception regarding the management of DC/CP inpatients in Italy during the rehabilitation stay. Data showed that about one-third of the 599 patients admitted to the 38 rehabilitation centers who responded to the survey had either a DC or a CP. TBI and cerebral hemorrhage were strongly associated with DC/CP, although the association was much stronger for TBI. The opinion survey showed some relevant discrepancies between some of the recommendations of the ICC and the corresponding perceptions of the respondents, especially regarding those items related to patients' clinical management (*i.e.*, surgical timing). Clear guidelines were indicated as the most crucial factor in improving the clinical pathways. Finally, the survey identified more self-reported "not sufficient experience" in critical areas related to the essential aspects of the management of these patients.

The results of this study were based on a simple survey regarding the care pathway of persons with DC/CP admitted to neurorehabilitation wards in Italy. The questionnaire was responded to by 38 different centers, a number which was superior to the original expectations. The survey design (which allowed reasonable control of typical respondent biases and the easiness of the questions) likely contributed to the excellent response rate. In particular, the possibility of answering most of the questions without needing retrospective data extractions was perhaps a major factor for success. Another success factor was the undertaking of a pilot test phase which confirmed that it allowed to correct errors and improve the usability of the questionnaire. Furthermore, collecting both basic epidemiological and conceptual information on relevant aspects of DC/CP pathways permitted putting the responses to the opinion section within an epidemiological context which, in turn, allowed to make comparisons with literature data on the same topic and provided quantitative information to substantiate the findings.

The epidemiological section showed that two-thirds of the respondent centers were in Northern Italy. This asymmetrical distribution of neurorehabilitation centers within Italy aligns with the GISCAR study.[27] In this 2012 prospective multicenter study on the epidemiology of sABI, the number of participating centers from Northern Italy equaled 67.3% of all centers. Another important datum that emerged from our survey is that while most centers were highly specialized in the neurorehabilitation of sABI (C75), about one-third were general rehabilitation centers (C56). Apart from a small statistically significant association between C56 and anoxic etiology, there were no other significant differences in prevalence and etiology between the two settings.

In our sample, the majority of DC (52.9%) were performed to counteract intracranial hypertension due to either SAH or ICH. This datum contrasts sharply with the cumulative prevalence of hemorrhagic DC (35.1%) across the studies reported in Table III. This difference could be explained considering the progressive trend of reduced incidence of TBI observed in Europe in recent years[28] linked to reduced road traffic accidents.[29] Also, another striking difference is related to the lower prevalence of DC due to ischemic brain injury in our sample compared to literature data (8.5% *vs*. 19.5%). This difference may be explained considering the improvement of long-term functional outcomes of ischemic stroke over the last five years due to intravenous thrombolysis and endovascular treatments for large vessel occlusion.[30]

The results of the opinion section suggest that Italian neurorehabilitation physicians considered both the timing and the organizational issues of CP an essential factor, likely related to the beneficial effect of CP on the outcome. Sveikata *et al.* suggest that improvement after CP should be considered a postoperative diagnostic criterion for SoT.[9] According to their study, reversal of the SoT may occur in up to 65% of all patients with DC. They also showed that the expected improvement is higher for TBI patients (86.7%) and lower for ischemic stroke (38.4%). The expected improvement for patients with DC due to hemorrhagic lesions is somehow intermediate (66.7%). However, the beneficial effect of CP is somehow time-dependent.[16, 31] Indeed, Sveikata *et al.* suggested that CP should be performed within a window of opportunity, which commences as soon as the brain swelling resides.[9] In particular, they showed that the odds of improvement after CP decreased by 4% for each day of delay after the resolution of brain edema and that delays of 135 days or longer were associated with no improvement. Furthermore, delaying CP can also increase the risk of recurrent infections,[13, 14] which could further delay CP and VPS for HC. In other words, needless delay of neurosurgical treatment may not only be associated with a poorer outcome but also with a prolonged rehabilitation length of stay (rLoS) in post-acute neuro rehabilitation wards.[3] Indeed, within the DC/CP subsample, the proportion of inpatients >three months after injury was higher (55.6%) than in the total sample (42.7%). In particular, CP inpatients >three months since injury approached almost two-thirds of the total.

Although expediting CP may contribute to reducing rLoS, it should be highlighted that its primary purpose is to improve the functional outcomes of DC patients. Indeed, considering that there is a time-dependent chance of improvement ranging from 38.4% (ischemia) to 86.7% (TBI),[9] every effort should be made to perform CP as soon as possible for any DC patient regardless of the etiology in the absence of clear contraindications (*i.e.*, on-going presence of brain swelling, enlarged ventricles with no clear cause, or proven infections).[15] In this respect, it is concerning that almost half of the DC inpatients were reported awaiting CP over three months after the injury, considering that about half were not even scheduled for intervention.

Of course, several clinical factors must be considered to establish optimal CP timing in individual patients. These clinical factors include the risk of CP-related infection, other complications such as HC, pre-CP morbidity, bleeding diathesis, and conditions related to the etiology of the DC. However, Sveikata *et al.* also suggested that organizational and logistical factors may delay CP.[9] From our survey, it is impossible to ascertain whether the long waiting times for transfer to neurosurgical wards (reported by most respondents) are attributable entirely to clinical factors or organizational and logistical issues. However, our data suggest that the latter may play a role. Indeed, 42% of centers reported an unsatisfying (or even a lack of) post-surgical follow-up. Furthermore, only 21.1% of the centers reported regular interdisciplinary meetings to discuss neurosurgical issues, whereas 18.4% of centers reported the unavailability of a referral neurosurgeon. Finally, 58% of rehabilitation units had to send patients to neurosurgical units likely to be far from the rehabilitation center.

By looking at the latter problem from another perspective, this may be the direct consequence of referring DC patients after the acute phase to neurorehabilitation centers which are far from the regional area of the neurosurgical center where the DC was performed. This practice, which may partially reflect the asymmetry in the geographical distribution of neurorehabilitation facilities in Italy, may become a critical factor for the whole interdisciplinary care pathway, given its logistical impact on subsequent surgical management. Indeed, putting an elective (although time-dependent) intervention such as CP in the surgical agenda of a neurosurgery department whose catchment area is quite distant from the rehabilitation center where the DC patient is currently admitted represents a logistical challenge, especially where routinary relationships and counseling activities are not regularly established between the two centers. At the same time, 29% of respondents reported that nearby neurosurgeries might be less prone to treat patients whose acute phase was managed elsewhere. The reasons for this further critical factor for the interdisciplinary care pathway may be diverse, including the limited national number of Bone Banks for the management of autologous CP (47% of respondents reported autologous bone as the material used to perform CP), the additional costs of heterologous CP, local health authority reimbursement and bed availability policies for extra-regional elective interventions, and, finally, continuity of surgical care issues.

Another issue where organizational and logistical aspects may have a negative impact on timing is related to the management of HC. It is well known that both DC and CP may be associated with HC, especially in TBI patients.[12, 32, 33] It is also known that delayed CP increases the rate of developing HC[34] and that the development of HC in DC patients increases the risk of subsequent infection of the cranioplasty surgical site.[35, 36] Regarding the outcome, earlier VPS is associated with better outcomes in HC patients,[34] untreated HC is associated with longer rLOS and a poorer outcome,[34, 37] whereas successfully treated HC does not worsen the global outcome, although it is likely to increase the rLoS.[32] Considering these data, close collaboration between the neurosurgical and rehabilitation teams is essential for establishing the appropriate timing for CP in the presence of HC, minimizing the risk of post-CP complications (*e.g.*, surgical site infection), and maximizing the chances of a favorable outcome.

There is conflicting evidence regarding the relationship of HC treatment with CP timing.[21, 33] However, VPS before DC may be associated with VPS hyper drainage, and VPS before or contemporary to CP may be associated with an increased risk of neurosurgical complications.[38] In our series, our interviewees reported that VPS was performed before CP in 15.9% of cases, a value similar to that (13.8%) reported by Dang *et al.*[38] Also, our survey reported severe complications in 50% of the cases, thus explaining the strong disagreement with large ES between the ICC statement indicating the opportunity to perform VPS after CP in the case of hydrocephalus and the neurorehabilitation physicians' perception of the actual practice. Considering this evidence, in patients with DC in whom the development of HC is suspected, CP should be performed as soon as possible in the absence of contraindications. Furthermore, following CP, the diagnostic and therapeutic pathway for HC should be hastened to increase the likelihood of a favorable outcome. Again, close collaboration between the neurosurgical and rehabilitation teams is an essential factor.

Another concerning gap between the theory and practice

is that our survey showed that 58% of respondents reported that MDRO colonization is still considered a contraindication for CP. Indeed, postoperative neurosurgical infections due to MDRO, such as Methicillin Resistant Staphylococcus Aureus (MRSA) and Carbapenemase Resistant Enterobacteriaceae (CRE), are increasing.[39, 40] MRSA is the germ responsible for CP surgical site infection (SSI) in variable percentages (from 22% up to 82% of cases).[35, 41] Still, other non-MRSA germs (*e.g.*, coagulase-negative staphylococcus aureus) are frequently involved.[35] Also, Gram-negative MDRO, such as Acinetobacter Baumanii,[39] Klebsiella Pneumoniae KPC positive, and Pseudomonas Aeruginosa, are known germs responsible for SSI in neurosurgery.[40] In general, being an MRSA nasal carrier increases the risk of MRSA-related SSI in neurosurgical patients (8% prevalence)[42] and, in more general terms, colonization by MDRO represents a risk factor for developing severe MDRO infections.[43] Also, there is some evidence that a positive MRSA colonization status, if associated with general risk factors predisposing to infections (*i.e.*, malignancy, diabetes, prior MRSA infection, immunosuppression) and traumatic injury, is likely to increase the risk of SSI due to MRSA.[42] Regardless of the germs involved, known risk factors for CP surgical site infection (SSI) include: a) surgical factors, such as prolonged surgical time,[41] bilateral convexity cranioplasty,[36] presence of hydrocephalus,[35, 36] previous neurosurgical operation;[41] b) comorbidities and general factors predisposing to infections such as diabetes,[41] low hemoglobin levels,[44] recent systemic infections,[44] and c) factors related to the neurological status of the patient, such as GOS<4 and motor deficits.[44]

It should be noted that in several clinical contexts (including rehabilitation and long-term care), colonization with an MDRO per se is not a sufficient condition to cause an infection. Indeed, the latter's development requires concurrent factors facilitating germ proliferation and spread, such as prolonged hospital stay, acute illnesses, indwelling devices, comorbidities.[45] Considering these data, the status of MDRO carrier (*e.g.*, nasal colonization with MRSA, respiratory colonization with AB, rectal colonization with CRE) in the absence of clinical, laboratory, and instrumental signs of active infection should not be, per se, a contraindication to performing CP. Thus, rather than needlessly postponing CP, infectious disease consultation should be undertaken to assess the risk of infection and to evaluate the opportunity for decolonization treatment.[22] At the same time, the rehabilitation team should make all possible efforts to minimize the risk of infection by addressing all modifiable risk factors before the intervention. These factors include achieving adequate glycemic control, hemoglobin levels, and a good nutritional state, considering that malnutrition, which induces immune depression, is a known and modifiable risk factor for infections.[46]

The survey showed a significant association between the respondents' setting and the "insufficient experience to answer" option, as the prevalence of the latter option response was much higher within C56 than C75. As the survey has demonstrated that DC/CP patients may be admitted during the rehabilitation phase also to general intensive rehabilitation wards, there is a need to provide specific training paths for rehabilitation physicians on neurosurgical aspects of sABI, such as DC, CP, and HC. In particular, we believe that adequate knowledge of the neurosurgical aspects is an essential prerequisite to managing this kind of patient at best, especially in contexts lacking neurosurgical resources and in the light of optimizing the chances of collaboration between the neurosurgical and rehabilitation team. Therefore, there is a need to provide opportunities for education and training on DC/CP management to a vaster audience of neurorehabilitation and rehabilitation physicians.

Limitations of the study

This study has several limitations. The first limitation is that it is difficult to ascertain the extent to which our rehabilitation unit sample can be considered representative of the population of Italian rehabilitation centers involved in the care of sABI. Indeed, to the authors' knowledge, a national registry including all rehabilitation institutions centers (both C56 and C75, as well as public or private) is unavailable. Thus, we may compare our data with those from the aforementioned GISCAR study.[27] In particular, the latter involved about 52 centers, including 827 patients, whereas our survey involved 38 centers, including 599 patients. Considering these figures, the numerosity of our sample appeared to be about one-quarter less than the GISCAR. In addition, however, we must consider that the GISCAR spanned three full years (2001-2003), whereas our survey was conducted in just three weeks, given the upcoming consensus conference. Despite this severe time constraint, 38 centers still responded to the survey. Notwithstanding this, the corresponding sample should be considered only partially representative of the population of the Italian rehabilitation centers.

Second, the survey reports opinions rather than actual data, such as those which could be collected within a prospective study. Third, the epidemiological section lacked several demographic (age, gender) and clinical information (individual patients' timing of CP and the actual

prevalence of HC within the sample, regardless of its association with DC/CP). Fourth, as no distinction was made between ICH and SAH, the comparisons between our data and previous literature regarding the prevalence of DC/CP and specific etiologies should be interpreted cautiously, given the different designs (cross-sectional *vs*. retrospective) of the studies. Fifth, the comparability of the results between our survey and the ICC[22] is limited. Indeed, the former preceded the latter and was focused on the clinical and pathway issues of patients with DC/CP regardless of the primary etiology of the sABI. In contrast, the ICC only regarded DC/CP issues only in the TBI population. Sixth, to make the conceptual linking possible, we had to change *post hoc* the survey's questions into statements. Finally, the cross-sectional picture provided by this study refers to the pre-Covid-19 era. Thus, it does not consider any epidemiological (*i.e.*, less traumatic cases during lockdowns),[47] care pathway management (*i.e.*, delays in non-urgent surgical procedures),[47] and access to rehabilitation services changes induced by the pandemic.

Conclusions

Considering that delaying CP may hinder neurological recovery and increase the risk of complications, there is a shared need to establish a unified neurosurgical care pathway based on early and close collaboration between the neurosurgical and the neurorehabilitation teams. The aim is to perform CP as soon as possible when the patient is clinically ready to be reconstructed (*i.e.*, the brain swelling has receded, there is no unclear cause of ventricle enlargement, and there are no proven infections).[15] The goal of expediting the pathway may be achieved by optimizing all those organizational and clinical factors which could otherwise lead to needless delays.[9]

Also, considering that the clinical and organizational management issues uncovered by this survey are the same across different pathologies, CP should be viewed as the second surgical time of DC[3] regardless of the etiology of the primary lesion. Although outcome trajectories may differ across etiologies,[9] this should not be a critical decisional factor for care delay or withdrawal. The risk is falling into the self-fulfilling prophecy trap, a well-known factor negatively affecting the outcome during the acute phase.[48]

While there is consensus between the ICC experts and neurorehabilitation physicians on the importance of performing CP, there may be different attitudes and perceptions, if not controversies, regarding the optimal clinical and care pathway management of patients with DC/CP. In this respect, it would be useful to acknowledge the perception of Italian neurosurgeons on these issues, to explore their point of view regarding any eventual gap between theoretical recommendations and actual practice.

Indeed, this acknowledgment could be the preparatory step toward an Italian Consensus Conference on the clinical and management pathways of DC/CP patients admitted to neurorehabilitation, which should involve not only neurosurgeons and rehabilitation physicians but also the scientific societies of all the stakeholders engaged in the DC/CP care pathways. Furthermore, as the caregiver involvement in the surgical decision-making processes is an essential element of quality of care in rehabilitation[49] (as recently recommended by an Italian Consensus Conference promoted by families of individuals affected by sABI[50]), the associations of patients' families should be considered stakeholders of paramount importance.

Finally, we believe there is a strong need for multicenter prospective studies focusing on the epidemiology and the outcomes of neurosurgical complications in patients admitted to neurorehabilitation.

References

1. De Tanti A, Zampolini M, Pregno S, Group CC; CC3 Group. Recommendations for clinical practice and research in severe brain injury in intensive rehabilitation: the Italian Consensus Conference. Eur J Phys Rehabil Med 2015;51:89–103.

2. Rossini Z, Nicolosi F, Kolias AG, Hutchinson PJ, De Sanctis P, Servadei F. The History of Decompressive Craniectomy in Traumatic Brain Injury. Front Neurol 2019;10:458.

3. Formisano R, Contrada M, Colli G, Lombardi F. Decompressive craniectomy and cranioplasty: the point of view of the neurorehabilitation team. J Neurosurg Sci 2020;64:494–5.

4. Tagliaferri F, Zani G, Iaccarino C, Ferro S, Ridolfi L, Basaglia N, *et al.* Decompressive craniectomies, facts and fiction: a retrospective analysis of 526 cases. Acta Neurochir (Wien) 2012;154:919–26.

5. Kim DB, Park SK, Moon BH, Cho BR, Jang DK, Jang KS. Comparison of craniotomy and decompressive craniectomy in large supratentorial intracerebral hemorrhage. J Clin Neurosci 2018;50:208–13.

6. Goedemans T, Verbaan D, Coert BA, Kerklaan BJ, van den Berg R, Coutinho JM, *et al.* Neurologic Outcome After Decompressive Craniectomy: Predictors of Outcome in Different Pathologic Conditions. World Neurosurg 2017;105:765–74.

7. Cooper DJ, Rosenfeld JV, Murray L, Arabi YM, Davies AR, D'Urso P, *et al.*; DECRA Trial Investigators; Australian and New Zealand Intensive Care Society Clinical Trials Group. Decompressive craniectomy in diffuse traumatic brain injury. N Engl J Med 2011;364:1493–502.

8. Hutchinson PJ, Kolias AG, Timofeev IS, Corteen EA, Czosnyka M, Timothy J, *et al.*; RESCUEicp Trial Collaborators. Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension. N Engl J Med 2016;375:1119–30.

9. Sveikata L, Vasung L, El Rahal A, Bartoli A, Bretzner M, Schaller K, *et al.* Syndrome of the trephined: clinical spectrum, risk factors, and impact of cranioplasty on neurologic recovery in a prospective cohort. Neurosurg Rev 2022;45:1431–43.

10. Wetzel-Weaver A, Bertero G, Aleton E, Turlan JL. Syndrome of the Trephined and Paroxysmal Sympathetic Hyperactivity in a 17-year-old minimally conscious state patient: A Case Report. Brain Inj 2021;35:1480–3.

11. Nasi D, Gladi M, Di Rienzo A, di Somma L, Moriconi E, Iacoangeli M, *et al.* Risk factors for post-traumatic hydrocephalus following decompressive craniectomy. Acta Neurochir (Wien) 2018;160:1691–8.

12. Vedantam A, Yamal JM, Hwang H, Robertson CS, Gopinath SP. Factors associated with shunt-dependent hydrocephalus after decompressive craniectomy for traumatic brain injury. J Neurosurg 2018;128:1547–52.

13. Pistoia F, Sacco S, Franceschini M, Sarà M, Pistarini C, Cazzulani B, *et al.* Comorbidities: a key issue in patients with disorders of consciousness. J Neurotrauma 2015;32:682–8.

14. Estraneo A, Loreto V, Masotta O, Pascarella A, Trojano L. Do Medical Complications Impact Long-Term Outcomes in Prolonged Disorders of Consciousness? Arch Phys Med Rehabil 2018;99:2523–2531.e3.

15. Iaccarino C, Kolias AG, Roumy LG, Fountas K, Adeleye AO. Cranioplasty Following Decompressive Craniectomy. Front Neurol 2020;10:1357.

16. Malcolm JG, Rindler RS, Chu JK, Chokshi F, Grossberg JA, Pradilla G, *et al.* Early Cranioplasty is Associated with Greater Neurological Improvement: A Systematic Review and Meta-Analysis. Neurosurgery 2018;82:278–88.

17. Di Stefano C, Rinaldesi ML, Quinquinio C, Ridolfi C, Vallasciani M, Sturiale C, *et al.* Neuropsychological changes and cranioplasty: A group analysis. Brain Inj 2016;30:164–71.

18. Jasey N, Ward I, Lequerica A, Chiaravalloti ND. The therapeutic value of cranioplasty in individuals with brain injury. Brain Inj 2018;32:318–24.

19. Kim BW, Kim TU, Hyun JK. Effects of Early Cranioplasty on the Restoration of Cognitive and Functional Impairments. Ann Rehabil Med 2017;41:354–61.

20. De Cola MC, Corallo F, Pria D, Lo Buono V, Calabrò RS. Timing for cranioplasty to improve neurological outcome: A systematic review. Brain Behav 2018;8:e01106.

21. Zheng F, Xu H, von Spreckelsen N, Stavrinou P, Timmer M, Goldbrunner R, *et al.* Early or late cranioplasty following decompressive craniotomy for traumatic brain injury: A systematic review and meta-analysis. J Int Med Res 2018;46:2503–12.

22. Iaccarino C, Kolias A, Adelson PD, Rubiano AM, Viaroli E, Buki A, *et al.* Consensus statement from the international consensus meeting on post-traumatic cranioplasty. Acta Neurochir (Wien) 2021;163:423–40.

23. Watson D. Correcting for Acquiescent Response Bias in the Absence of a Balanced Scale: An Application to Class Consciousness. Sociol Methods Res 1992;21:52–88.

24. Furnham A. Response bias, social desirability and dissimulation. Pers Individ Dif 1986;7:385–400.

25. Blankenship A. Psychological Difficulties in Measuring Consumer Preference. J Mark 1942;6:66–75.

26. Ziai WC, Port JD, Cowan JA, Garonzik IM, Bhardwaj A, Rigamonti D. Decompressive craniectomy for intractable cerebral edema: experience of a single center. J Neurosurg Anesthesiol 2003;15:25–32.

27. Zampolini M, Zaccaria B, Tolli V, Frustaci A, Franceschini M; GISCAR Group. Rehabilitation of traumatic brain injury in Italy: a multi-centred study. Brain Inj 2012;26:27–35.

28. Brazinova A, Rehorcikova V, Taylor MS, Buckova V, Majdan M, Psota M, *et al.* Epidemiology of Traumatic Brain Injury in Europe: A Living Systematic Review. J Neurotrauma 2021;38:1411–40.

29. Lepard JR, Spagiari R, Corley J, Barthélemy EJ, Kim E, Patterson R, *et al.* Differences in outcomes of mandatory motorcycle helmet legislation by country income level: A systematic review and meta-analysis. PLoS Med 2021;18:e1003795.

30. Ghaith HS, Elfil M, Gabra MD, Nawar AA, Abd-Alkhaleq MS, Hamam KM, *et al.* Intravenous thrombolysis before mechanical thrombectomy for acute ischemic stroke due to large vessel occlusion; should we cross that bridge? A systematic review and meta-analysis of 36,123 patients. Neurol Sci 2022;43:6243–69.

31. Yang NR, Song J, Yoon KW, Seo EK. How Early Can We Perform Cranioplasty for Traumatic Brain injury After Decompressive Craniectomy? A Retrospective Multicenter Study. World Neurosurg 2018;110:e160–7.

32. Linnemann M, Tibæk M, Kammersgaard LP. Hydrocephalus during rehabilitation following severe TBI. Relation to recovery, outcome, and length of stay. NeuroRehabilitation 2014;35:755–61.

33. Nasi D, Dobran M, Di Rienzo A, di Somma L, Gladi M, Moriconi E, *et al.* Decompressive Craniectomy for Traumatic Brain Injury: The Role of Cranioplasty and Hydrocephalus on Outcome. World Neurosurg 2018;116:e543–9.

34. Kowalski RG, Weintraub AH, Rubin BA, Gerber DJ, Olsen AJ. Impact of timing of ventriculoperitoneal shunt placement on outcome in posttraumatic hydrocephalus. J Neurosurg 2018;•••:1–12.

35. Zanaty M, Chalouhi N, Starke RM, Chitale R, Hann S, Bovenzi CD, *et al.* Predictors of infections following cranioplasty: a retrospective review of a large single center study. ScientificWorldJournal 2014;2014:356042.

36. Zanaty M, Chalouhi N, Starke RM, Clark SW, Bovenzi CD, Saigh M, *et al.* Complications following cranioplasty: incidence and predictors in 348 cases. J Neurosurg 2015;123:182–8.

37. Weintraub AH, Gerber DJ, Kowalski RG. Posttraumatic Hydrocephalus as a Confounding Influence on Brain Injury Rehabilitation: Incidence, Clinical Characteristics, and Outcomes. Arch Phys Med Rehabil 2017;98:312–9.

38. Dang Y, Ping J, Guo Y, Yang Y, Xia X, Huang R, *et al.* Cranioplasty for patients with disorders of consciousness. Ann Palliat Med 2021;10:8889–99.

39. Mohammed N, Savardekar AR, Patra DP, Narayan V, Nanda A. The 21st-century challenge to neurocritical care: the rise of the superbug Acinetobacter baumannii. A meta-analysis of the role of intrathecal or intraventricular antimicrobial therapy in reduction of mortality. Neurosurg Focus 2017;43:E8.

40. Orsi GB, Scorzolini L, Franchi C, Mondillo V, Rosa G, Venditti M. Hospital-acquired infection surveillance in a neurosurgical intensive care unit. J Hosp Infect 2006;64:23–9.

41. Lee CH, Chung YS, Lee SH, Yang HJ, Son YJ. Analysis of the factors influencing bone graft infection after cranioplasty. J Trauma Acute Care Surg 2012;73:255–60.

42. Akins PT, Belko J, Banerjee A, Guppy K, Herbert D, Slipchenko T, *et al.* Perioperative management of neurosurgical patients with methicillin-resistant Staphylococcus aureus. J Neurosurg 2010;112:354–61.

43. McConville TH, Sullivan SB, Gomez-Simmonds A, Whittier S, Uhlemann AC. Carbapenem-resistant Enterobacteriaceae colonization (CRE) and subsequent risk of infection and 90-day mortality in critically ill patients, an observational study. PLoS One 2017;12:e0186195.

44. Rosseto RS, Giannetti AV, de Souza Filho LD, Faleiro RM. Risk Factors for Graft Infection After Cranioplasty in Patients with Large Hemicranial Bony Defects. World Neurosurg 2015;84:431–7.

45. Drinka P, Niederman MS, El-Solh AA, Crnich CJ. Assessment of risk factors for multi-drug resistant organisms to guide empiric antibiotic selection in long term care: a dilemma. J Am Med Dir Assoc 2011;12:321–5.

46. Bourke CD, Berkley JA, Prendergast AJ. Immune Dysfunction as a Cause and Consequence of Malnutrition. Trends Immunol 2016;37:386–98.

47. Servadei F, Cannizzaro D. Effects on traumatic brain injured patients of COVID pandemia: which responses from neurosurgical departments? Acta Neurochir (Wien) 2021;163:1051–2.

48. Izzy S, Compton R, Carandang R, Hall W, Muehlschlegel S. Self-fulfilling prophecies through withdrawal of care: do they exist in traumatic brain injury, too? Neurocrit Care 2013;19:347–63.

49. Girardi G, Farnese ML, Scarponi F, De Tanti A, Bartolo M, Intiso D, *et al.* User-centered practices in the eyes of informal caregivers of inpatients with severe acquired brain injury: needs, caring experience, and satisfaction. Brain Inj 2021;35:1402–12.

50. Giuria Conferenza di Consenso. Seconda conferenza nazionale di consenso delle Associazioni: Documenti Conclusivo della Giuria. 2021.

Conflicts of interest
The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions
Anna Estraneo and Antonio De Tanti shared last authorship. Rita Formisano, Anna Estraneo, Fabio La Porta and Antonio De Tanti equally contributed to the study design and to devising the survey; Fabio La Porta gave substantial contributions to the acquisition and analysis of data. Fabio La Porta and Antonio De Tanti contributed equally to interpreting the data and drafting the manuscript. All authors have participated in critically revising the manuscript and read and approved the final version of the manuscript.

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