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ABSTRACT

Background Following traumatic brain injury (TBI), the clinical focus is often on disability. However, patients' perceptions of well-being can be discordant with their disability level, referred to as the 'disability paradox'. We aimed to examine the relationship between disability and health-related quality of life (HRQoL) following TBI, while taking variation in personal, injury-related and environment factors into account.

Methods We used data from the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury study. Disability was assessed 6 months post-injury by the Glasgow Outcome Scale-Extended (GOSE). HRQoL was assessed by the SF-12v2 physical and mental component summary scores and the Quality of Life after Traumatic Brain Injury overall scale. We examined mean total and domain HRQoL scores by GOSE. We quantified variance in HRQoL explained by GOSE, personal, injury-related and environment factors with multivariable regression.

Results Six-month outcome assessments were completed in 2075 patients, of whom 78% had mild TBI (Glasgow Coma Scale 13–15). Patients with severe disability had higher HRQoL than expected on the basis of GOSE alone, particularly after mild TBI. Up to 50% of patients with severe disability reported HRQoL scores within the normative range. GOSE, personal, injury-related and environment factors explained a limited amount of variance in HRQoL (up to 29%).

Conclusion Contrary to the idea that discrepancies are unusual, many patients with poor functional outcomes reported well-being that was at or above the boundary considered satisfactory for the normative sample. These findings challenge the idea that satisfactory HRQoL in patients with disability should be described as 'paradoxical' and question common views of what constitutes 'unfavourable' outcome.

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INTRODUCTION

Disability relates to a set of difficulties a person may experience when interacting with their social and physical environments.[1 2] Disability is common following moderate and severe traumatic brain injury (TBI), and increasingly recognised as a consequence of mild TBI.[3] Following TBI, individuals often experience impairments in different aspects of their life, including physical, social and cognitive limitations, which may impact their well-being.[4–8]

Clinical decisions about the management of TBI are often based on the likelihood of the person remaining dependent on others in daily life and therefore having impaired quality of life.[9] However, healthy people can overestimate the emotional impact that chronic illness and disability will have on a persons' well-being.[10] Furthermore, patients' perceptions of quality of life can be discordant with their objective health status.[11] This phenomenon has been described as the 'disability paradox': a discrepancy between severe disability that is observable by others and good quality of life reported by the patient.[11] However, critics argue that the 'paradox' depends on the assumption that disability determines well-being.[12]

Previous reports consistent with the idea of a 'disability paradox' indicates that patients with severe disability several months following TBI can experience good or excellent well-being.[13] A common explanation for this phenomenon is anosognosia: lack of awareness of disability, as a result of neurological impairment.[14] In the classic descriptions of anosognosia, the individual may, for example, deny having hemiparesis after stroke.[15] Anosognosia following TBI might be related to behavioural disorders, frontal lobe syndromes and/or problems with social cognition. Other explanations for the 'disability paradox' include psychological processes such as coping,[11] and personal and environment factors:[16] for instance, how patients experience disabilities might be affected by employment, preinjury mental health and satisfaction with social support.[12] This is in agreement with the way in which the relationship between health and disability is described by the WHO: disability is a complex construct involving an interaction between the person and their environment.[1]

To date, the discordance between disability level and well-being and the 'disability paradox' have mainly been described as a theoretical construct,[11–13 16] or observed in practice without receiving much attention in empirical studies.

We aimed to examine the relationship between functional outcome, and health-related quality of life (HRQoL) in individuals 6 months following TBI, while taking variation in personal, injury-related and environment factors into account. We hypothesised that the relationship between disability and HRQoL differs by injury severity.

Predictors of functional outcome for mild injuries differ from those for more severe injuries,[17] suggesting that these subgroups have distinctive characteristics. Further, we hypothesised that contextual factors, including personal, injury-related and environment factors contribute to explaining variation in HRQoL.

METHODS

Study population

We analysed data from the Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) study. This is a prospective, multicentre, longitudinal, observational study.[18 19] Data were collected for patients with a clinical diagnosis of TBI and an indication for CT, presenting within 24 hours of injury in one of the 59 participating centres.

Participants were recruited from December 2014 to December 2017 in 18 countries across Europe and Israel. In our study, patients were included if they were aged ≥16 years and had available GOSE, and SF-12v2 or Quality of Life after Traumatic Brain Injury overall scale (QOLIBRI-OS) scores at 6-months post-injury.

Data for the CENTER-TBI study were entered by participating sites on the Quesgen e-CRF (Quesgen Systems, USA), hosted on the International Neuroinformatics Coordinating Facility (INCF) platform, and extracted via the INCF Neurobot tool (INCF, Sweden) (database Core 2.1). Informed consent was obtained from all participants according to local and national requirements.

In our study, we included 2075 patients aged 16 years or over who had completed the outcome assessments at 6 months post-injury (online supplemental file 1). Patients with missing questionnaires or with proxy responses on HRQoL assessments were excluded.

Outcome assessment

Disability

The Glasgow Outcome Scale-Extended (GOSE) is widely used as a global measure of functional outcome and disability. The scale has eight categories: (1) death, (2) vegetative state, (3) lower severe disability, (4) upper severe disability, (5) lower moderate disability, (6) upper moderate disability, (7) lower good recovery and (8) upper good recovery[20] (online supplemental table 1). In CENTER-TBI, the GOSE was assessed as a structured interview or a questionnaire completed by the patient or a carer. At 6 months follow-up, the format of the assessment was an interview in 79% cases and a questionnaire in 20% (online supplemental table 2). The respondent for the GOSE was almost always the patient, either alone or with a relative or carer (98%). The GOSE was scored centrally combining the ratings of the interviews and the questionnaires. Missing GOSE values were imputed based on GOSE measurements at other time points if available.[21]

Health-related quality of life

We used the Short Form-12 V.2 (SF-12v2) and the QOLIBRI-OS to assess health-related quality of life (HRQoL). The SF-12v2 is a 12-item patient-reported HRQoL outcome which assesses multiple aspects of health-related functioning and well-being.[22] The SF-12v2 comprises eight subscales and two summary scores: physical functioning, role limitations due to physical health, bodily pain and general health perceptions, are included in the physical component summary (PCS) score, and vitality, social functioning, role limitations due to emotional health and general mental health, are included in the mental component summary (MCS) score. The PCS emphasises aspects of functional status, while the MCS incorporates well-being including mental health.[23] The norm-based T-scores (standardised to mean 50 and SD of 10) were calculated for the MCS and PCS. MCS and PCS scores range between 2 (poorest possible HRQoL) and 74 (best possible HRQoL). For the SF-12v2, scores of 45 and above are considered within the normative range for the general population, scores of 40–45 are borderline, and scores below 40 are considered impaired.[22]

The QOLIBRI-OS is a six-item patient-reported HRQoL outcome specifically developed for patients following TBI.[24] The QOLIBRI-OS assesses satisfaction with aspects of life (cognition, self, daily life and autonomy, social relationships, current situation and future prospects) and ranges from 0 (poorest possible HRQoL) to 100 (best possible HRQoL). Scores of 61 and above are considered within the normative range, scores of 52–60 are considered borderline and scores below 52 are considered low or impaired.[25]

Contextual factors related to HRQoL following TBI

We studied the following personal and injury-related factors that are relevant to HRQoL: age,[26] sex,[26] marital status, level of education,[27] type of employment preinjury,[27] preinjury mental health problems,[28] preinjury substance abuse,[29] preinjury health status (The American Society of Anesthesiologists—physical status classification system (ASA-PS)), cause of injury, injury severity,[29 30] the presence of intracranial abnormality and major extracranial injury (MEI).[31] Initial injury severity was assessed with the GCS. TBI was considered mild in patients with GCS 13–15, moderate in patients with GCS 9–12 and severe in patients with GCS of 3–8.[19] The definition of 'mild' injury allows that patients may have an abnormality on CT.[3] Preinjury health status was assessed with the ASA-PS; patients are categorised as 'normal healthy patient', 'mild systemic disease', 'severe systemic disease' or 'severe systemic disease that is a constant threat to life'. The categories 'severe systemic disease' and 'severe systemic disease that is constant threat to life' were combined. MEI was defined as an Abbreviated Injury Scale≥3 regarding the following body regions; face, thoracic/ lumbar spine, thorax/chest, abdomen/ pelvic contents, extremities and pelvic girdle, or external (skin), thus excluding head and neck. Environment factors involve satisfaction with social support, satisfaction with support from the hospital and health services and satisfaction with support from rehabilitation services 6 months post-injury.[26 27 32]

Statistical analyses

Descriptive statistics are presented as medians (IQR) or frequencies (percentage).

We examined the relationships between disability and HRQoL in three ways: (I) we calculated the percentage of patients by GOSE category that have scores in the normative range on the QOLIBRI-OS and MCS; (II) we examined differences between the PCS and the MCS as a measure of dissociation between physical and mental HRQoL and (III) we studied the association of the GOSE and HRQoL using linear regression analysis, including personal, injury-related and environment factors.

All analyses were performed separately for individuals with mild (Glasgow Coma Scale (GCS) 13–15) and moderate/severe (GCS 3–12) TBI. The decision to combine patients with moderate and severe TBI was motivated by the sample size (Moderate/severe TBI N=466), and the limited number of patients classified as moderate TBI (N=149). To account for differences in the relationship between GOSE and HRQoL following mild, moderate and severe TBI, we performed two-way analysis of

variance (ANOVA) for SF-12 PCS, MCS and QOLIBRI-OS. The relationship between HRQoL following TBI and the GOSE, personal, injury-related and environment factors were analysed with linear regression analyses. The contribution of predictors to the explained variance (R^2) for each outcome was shown graphically by the partial R^2. Furthermore, the associations between the GOSE and the MCS and QOLIBRI-OS total score, adjusted for personal, injury-related and environment factors were shown graphically.

Analyses are performed with R statistical software (R V.3.6.0). We used the *rms* package to fit the regression models.[33]

RESULTS

Study sample

We included 2075 adult patients who completed the GOSE and SF-12v2 or the QOLIBRI-OS 6 months post-injury (online supplemental figure 1). SF-12v2 and QOLIBRI-OS completion rates at follow-up differed by GOSE category (online supplemental table 3): patients with GOSE three had the lowest completion rates (QOLIBRI-OS: 60%, SF-12v2: 65%), while completion rates for patients with higher levels of functioning were higher and generally above 75%.

The median age was 51 years (IQR=32–64) (table 1). Most patients (78%) were classified as having a mild TBI. A third (35%) had MEI. Fifty-three per cent was employed, 23% was retired, and 18% unemployed. About 10% had preinjury mental health problems. Moreover, 40% reported preinjury comorbid health issues.

Patients following moderate/severe TBI were younger, more often male and more often involved in traffic accidents than patients after mild TBI (table 1). Rehabilitation was less often received by patients after mild TBI (24%) compared with those after moderate/severe TBI (79%) (table 2).

Six months after TBI, 186 patients experienced severe disability (9%) (GOSE 3–4), 528 patients experienced moderate disability (25%) (GOSE 5–6) and 1361 (66%) could be classified as having a good recovery (GOSE 7–8) (table 2).

Health-related quality of life stratified by injury severity and disability

Overall, SF-12 PCS, MCS and QOLIBRI-OS scores 6 months following TBI increased with the GOSE (figure 1). In both severity groups, the PCS showed an almost linear relationship with the GOSE. This contrasts with the relationship with the MCS, particularly at lower levels of outcome. Specifically, following mild TBI, patients with a GOSE of 3–4, reported higher MCS scores than patients with a GOSE of 5 (mean 42 (95% CI 38 to 47) and 48 (41 to 47) for GOSE 3 and 4 vs 38 (36 to 40) for GOSE 5) (online supplemental table 4). The results for the QOLIBRI-OS in the mild group mirror those of the MCS (QOLIBRI-OS mean 45 (95% CI 37 to 54) and 54 (48 to 60) for GOSE 3 and 4 vs 48 (44 to 52) for GOSE 5).

Based on the ANOVA, there were significant differences on all HRQoL outcomes by GCS and GOSE. The interaction between GCS and GOSE was significant for MCS ($F=4.137$, df 1, $p<0.01$) but not for QOLIBRI-OS ($F=0.55$, df 1, $p=0.46$) and PCS ($F=0.098$, df 1, $p=0.75$).

For patients following mild TBI, the lowest mean score on the MCS was reported for those with lower moderate disability (GOSE 5) (online supplemental table 4) (mean 38 (95% CI 36 to 40) compared with >42 (95% CI 38 to 47)). Following moderate and severe TBI, patients with lower severe disabilities (GOSE 3) reported the lowest mean MCS scores (mean 41

Table 1 Patients' demographic and injury characteristics

Characteristics	All patients* 2075	Mild TBI (GCS 13–15)† 1609	Moderate and severe TBI (GCS 3–12)† 466	P value‡
Demographics				
Age median (IQR)	51 (32–64)	53 (35–66)	41 (26–55)	<0.001
% Male sex	65	63	70	>0.05
Marital status, N (%)				>0.05
Married	1069 (52)	856 (53)	213 (46)	
Missing	117 (6)	87 (5)	30 (6)	
Highest level of education				<0.001
College/Uni degree	548 (26)	453 (28)	95 (20)	
Currently in school/ with diploma or degree-oriented programme	440 (21)	340 (21)	100 (22)	
None/primary school	246 (12)	202 (13)	44 (9)	
Secondary/high school	620 (30)	463 (29)	157 (34)	
Missing	221 (11)	151 (9)	70 (15)	
Employment type N (%)				<0.001
Working	1109 (53)	842 (52)	267 (57)	
Homemaker	29 (1)	25 (2)	4 (1)	
Retired	469 (23)	412 (26)	57 (12)	
Sick leave/unable to work	49 (2)	36 (2)	13 (3)	
Student	199 (10)	142 (9)	587[12]	
Unemployed	91 (4)	66 (4)	25 (5)	
Missing	129 (6)	86 (5)	43 (9)	
Employment status, N (%)				<0.001
Yes	1109 (53)	842 (52)	267 (57)	
Retired	469 (23)	412 (26)	57 (12)	
No	368 (18)	269 (17)	99 (21)	
Missing	129 (6)	86 (5)	43 (9)	
ASA preinjury health status,§§ N (%)				
Healthy	1223 (59)	917 (57)	307 (66)	
Mild disease	663 (32)	538 (33)	125 (27)	
Severe disease	175 (8)	146 (9)	29 (6)	
Missing	14 (1)	8 (1)	6 (1)	
Preinjury substance abuse¶¶				<0.001
Yes	45 (2)	27 (2)	18 (4)	
Missing	19 (1)	8 (1)	11 (2)	
Pre-injury mental health problems,** N (%)				<0.01
Yes	205 (10)	169 (11)	36 (8)	
Missing	23 (1)	8 (1)	11 (2)	
Injury characteristics				
Cause of injury, N (%)				<0.001
Road traffic incident	851 (41)	618 (38)	233 (50)	
Incidental fall	908 (44)	751 (47)	157 (34)	
Other non-intentional injury	174 (8)	136 (8)	38 (8)	
Violence/assaults	104 (5)	79 (5)	25 (5)	
Missing	38 (2)	25 (2)	13 (3)	
Major extracranial injury,†† N (%)				<0.001
Yes	744 (35)	450 (28)	269 (58)	
ISS	13 (8–25)	10 (5–18)	29 (25–41)	<0.001
Any intracranial abnormality,‡‡ N (%)				<0.001
Present	863 (42)	711 (44)	385 (83)	
Missing	116 (6)	80 (5)	36 (8)	

Continued

Table 1 Continued

Characteristics	All patients* 2075	Mild TBI (GCS 13–15)† 1609	Moderate and severe TBI (GCS 3–12)† 466	P value‡

Statistics are for the difference between mild and moderate/severe subgroups.
*Patients<16 years of age (n=149), proxy responses (n=251), patients with missing GOSE (n=8) and those that did not complete the HRQoL questionnaires (n=476) were excluded.
†Initial injury severity was assessed with the GCS. TBI was considered mild in patients with GCS 13–15, moderate in patients with GCS 9–12, and severe in patients with GCS of 3–8.
‡P values from ANOVA for continuous and χ^2 statistics for categorical variables.
§Preinjury health status was assessed with the American Society of Anesthesiologists—physical status classification system (ASA-PS).
¶Patients with a history of substance abuse disorder prior to the injury.
**Patients with a history of anxiety, depression, sleep disorders, or schizophrenia prior to the injury.
††Patients with an Abbreviated Injury Scale≥3 regarding the all body regions excluding head and neck.
‡‡The presence of intracranial traumatic abnormalities was assessed through the first CT scan after injury, and indicates whether any of the 12 following abnormalities was present: mass lesion, hematoma, epidural hematoma, acute or subacute subdural hematoma, subdural collection mixed density, contusion, TAI, traumatic subarachnoid haemorrhage, intraventricular haemorrhage, midline shift or cisternal compression.
AIS, Abbreviated Injury Scale; ASA-PS, The American Society of Anesthesiologists-physical status classification system; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; MEI, major extracranial injury; N, number; TBI, traumatic brain injury.

(95% CI 39 to 45) compared with >42 (39 to 45)). For four SF-12 subscales, namely 'bodily pain', 'general health', 'role emotional' and 'mental health', and the QOLIBRI-OS items 'how your brain is working', 'feelings and emotions', 'social life' and 'current situation and future prospects' individuals following mild TBI with lower moderate disability (GOSE 5) scored lower than patients with upper severe disability (GOSE 4) (online supplemental table 4). The median score on the PCS increased with recovery level on the GOSE. Similarly, the MCS and QOLIBRI-OS scores generally increased with recovery level on the GOSE, but in patients following mild TBI, HRQoL scores did not increase from GOSE 3 to 5.

Discordance between disability and health-related quality of life: the 'disability paradox'

Similar to the trends depicted in figure 1, a higher percentage of patients following mild TBI with upper severe disability (GOSE 4) reported HRQoL scores within the normative range than patients with lower moderate disability (GOSE 5) (MCS 50% vs 30%; QOLIBRI-OS 42% vs 35%) (table 3).

Following mild TBI, up to half of the individuals with severe disability (N=93) had normative QOLIBRI-OS and MCS scores 6 months following TBI (QOLIBRI-OS 29% and 42%, MCS 40% and 50%) (table 3). In contrast, a smaller proportion of individuals with severe disabilities had normative PCS scores (11% and 24%). Following moderate and severe TBI, more than a third of individuals with severe disability (N=88) had normative QOLIBRI-OS and MCS scores 6 months following TBI (QOLIBRI-OS 40% and 37%; MCS 26% and 13%) (table 3).

Second, we calculated the difference between the PCS and the MCS by recovery level on the GOSE. Patients with severe disability had larger mean differences between the MCS and PCS compared with patients with moderate disability and good recovery (table 3). The difference for patients with severe disability was nearly 10 points, which is equivalent to one SD at the population level. This implies that severely disabled individuals have a substantial discordance between the PCS and MCS.

Table 2 Patients' satisfaction with social support, use of rehabilitation services and outcomes 6-month post-injury

Characteristics	All patients 2075	Mild TBI (GCS 13–15)† 1609	Moderate and severe TBI (GCS 3–12)† 466	P value‡
*Social support 6-month post-injury**				
Satisfaction with social support, N (%)				>0.05
Low	265 (13)	219 (14)	46 (10)	
High	1755 (85)	1347 (84)	408 (88)	
Missing	55 (3)	43 (3)	12 (3)	
Satisfaction with social support from hospital and health services, N (%)				<0.05
Low	202 (10)	172 (11)	30 (6)	
High	1800 (87)	1386 (86)	414 (89)	
Missing	73 (4)	51 (3)	22 (5)	
Satisfaction with social support from rehabilitation services, N (%)				<0.001
Low	404 (20)	322 (20)	82 (18)	
High	1473 (71)	1108 (69)	365 (78)	
Missing	198 (10)	179 (11)	19 (4)	
Type of rehabilitation services received, N (%)				<0.001
No rehabilitation	1290 (64)	1194 (76)	96 (21)	
In-patient/residential	408 (20)	150 (10)	258 (57)	
Outpatient/community	234 (16)	221 (14)	98 (22)	
Six-month functional outcome				
Glasgow Outcome Scale-Extended 6-month post-injury				<0.001
Lower severe disability	77 (4)	35 (2)	42 (9)	
Upper severe disability	109 (5)	58 (4)	51 (11)	
Lower moderate disability	225 (11)	116 (7)	109 (23)	
Upper moderate disability	303 (15)	203 (13)	100 (22)	
Lower good recovery	491 (24)	417 (26)	74 (16)	
Upper good recovery	870 (42)	780 (49)	90 (19)	

Statistics are for the difference between mild and moderate/ severe subgroups.
*Satisfaction with social support in general, from hospital and health services and from rehabilitation services were assessed 6-month post-injury. The response categories 'not at all', 'slightly' and 'moderately' were classified as 'low' satisfaction with social support, and the response categories 'quite', and 'very' were classified as 'high' satisfaction with social support.
†Initial injury severity was assessed with the GCS. TBI was considered mild in patients with GCS 13-15, moderate in patients with GCS 9-12, and severe in patients with GCS of 3-8.
GCS, Glasgow Coma Scale; TBI, traumatic brain injury.

The relation between disability, contextual factors and HRQoL

The GOSE had the largest contribution to explaining the variance of HRQoL compared with personal, injury-related and environment factors (figure 2).

While adjusting for personal, injury-related and environment factors in patients with mild TBI, estimates of the MCS and QOLIBRI-OS for patients with GOSE 5 were lower than estimates for patients with GOSE 3–4 (figure 3). Thus, personal and injury-related factors (including MEI) and satisfaction with social support did not explain the discrepancies between GOSE and HRQoL in patients following mild TBI.

Besides the GOSE, satisfaction with social support 6 months following TBI contributed to explaining the variance in HRQoL (figure 2). Independent of initial injury severity based on GCS, patients with lower moderate disabilities (GOSE 5) were least satisfied with the support they received from rehabilitation (67% vs ≥70% for mild and 75% vs ≥79% for moderate and severe TBI) (online supplemental table 5). As expected, patients with moderate disability (GOSE 5–6) were less likely than patients with severe disability (GOSE 3–4) to receive rehabilitation 6

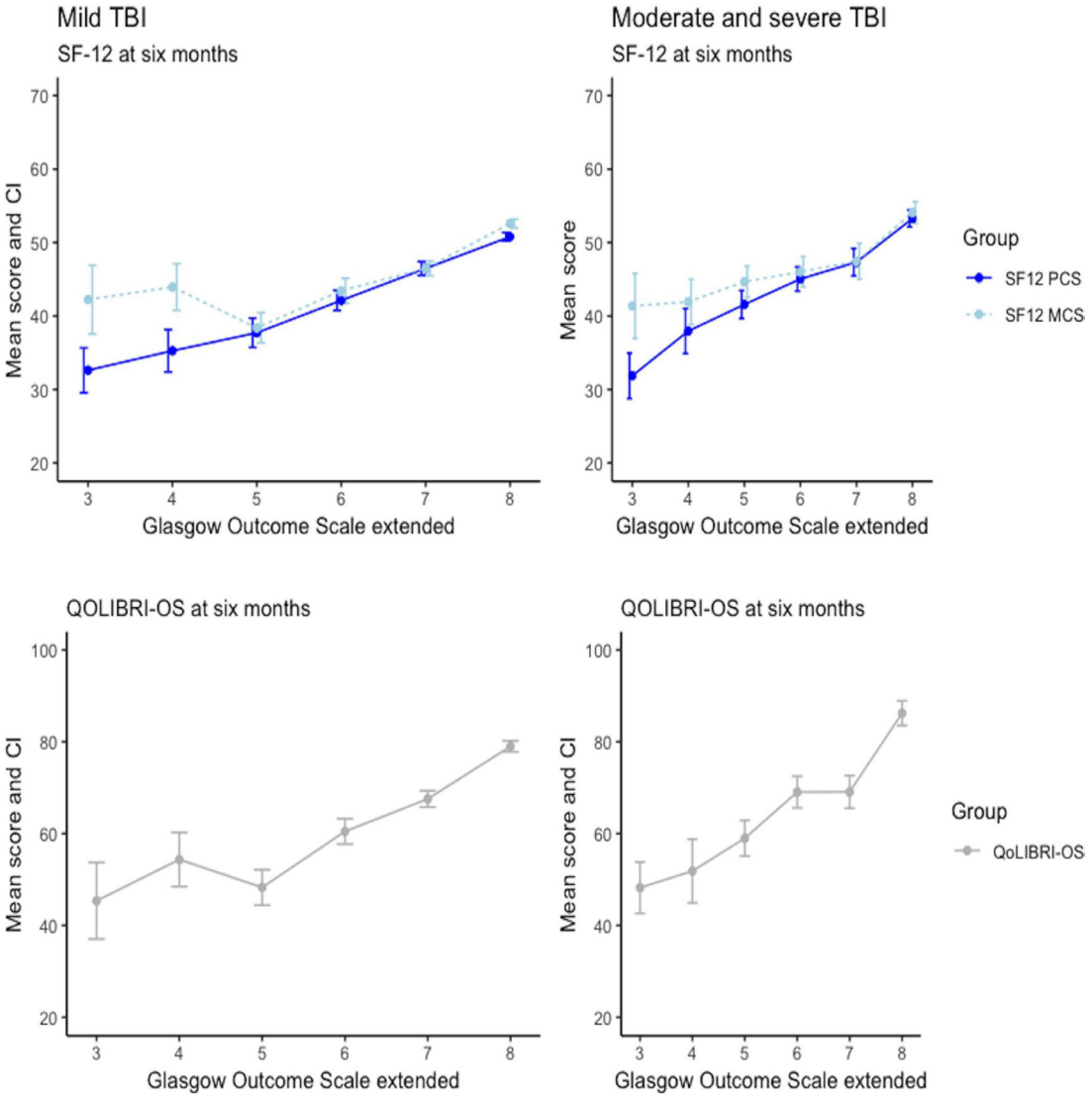

Figure 1 Plots of the SF-12v2 physical and mental health component summary scores (top) and the QOLIBRI-OS (bottom) by time point for mild (left) and moderate and severe TBI (right). The points are means and error bars are 95% CI. QOLIBRI-OS, Quality of Life after Traumatic Brain Injury overall scale; TBI, traumatic brain injury.

months post-injury (54%–62% vs <51% for mild TBI, respectively; 9%–19% vs <5% for moderate/severe TBI respectively) (online supplemental table 6).

Up to 29% (mild) and 28% (moderate and severe) of the variance in QOLIBRI-OS and 21% (mild) and 11% (moderate and severe) of the variance in MCS were explained by the combination of GOSE, personal and injury related characteristics and satisfaction with social support at 6 months post-injury.

DISCUSSION

We examined the relationship between disability assessed with the GOSE and HRQoL measured with the SF12v2 MCS and QOLIBRI-OS 6 months following TBI in the CENTER-TBI study. Following mild TBI, patients can have poor functional outcomes, which is consistent with growing awareness that patients classified as mild by GCS criteria can suffer a range of problems.[3] In patients following mild TBI, HRQoL did not decrease linearly with greater disability. Specifically, patients with severe disability on the GOSE reported higher MCS and QOLIBRI-OS scores than patients with moderate disabilities. Furthermore, between a third and half of patients with severe disabilities reported HRQoL within the normative range. Our study therefore confirms that individuals' perceptions of aspects of well-being and mental health are often discordant with their objective functioning following TBI.

Our findings are consistent with prior studies describing good or excellent well-being and quality of life following TBI.[13 34] Furthermore, our findings imply that satisfactory HRQoL in patients with disabilities is not a 'paradox', since individuals frequently report HRQoL within the normative range following TBI. Discordance between disability and HRQoL should therefore be regarded as a characteristic of TBI outcomes. Characterising HRQoL within the normative range despite severe disability as a 'paradox' has serious shortcomings, as it implies that patients with severe disability cannot normally experience satisfactory HRQoL.[13] Discrepancies between disability and HRQoL have been observed in prior studies in TBI.[35–37] To provide quantification of the discordance between physical and mental health, we therefore examined the difference between the SF-12v2 MCS and PCS. Similarly, patients with severe disabilities had the largest discordance between the MCS and PCS.

Table 3 Number and percentage of patients with HRQoL scores within the normative range 6-month post-injury, and mean differences between the MCS and PCS

GOSE	QOLIBRI-OS >61	SF-12 MCS >45	SF-12 PCS >45	Mean MCS – PCS (SD)
Mild TBI (n=1609)				
3 (n=35)	9 (29)	14 (40)	4 (11)	9.62 (15.58)
4 (n=58)	24 (42)	29 (50)	14 (24)	8.68 (17.34)
5 (n=116)	41 (35)	35 (30)	33 (29)	0.68 (17.20)
6 (n=203)	109 (54)	93 (46)	89 (44)	1.31 (16.21)
7 (n=417)	281 (68)	244 (59)	259 (62)	0.00 (14.44)
8 (n=780)	671 (88)	631 (82)	605 (79)	1.79 (11.42)
Moderate and severe TBI (n=466)				
3 (n=42)	13 (32)	16 (38)	5 (12)	9.50 (20.78)
4 (n=51)	19 (38)	20 (41)	13 (27)	3.97 (15.82)
5 (n=109)	56 (52)	57 (53)	46 (43)	3.09 (14.97)
6 (n=100)	71 (72)	57 (58)	52 (53)	0.97 (12.78)
7 (n=74)	52 (72)	44 (59)	45 (61)	0.12 (14.51)
8 (n=90)	84 (95)	76 (85)	83 (93)	0.82 (9.20)

The data are shown by Glasgow Outcome Scale-Extended categories separately for mild and moderate/severe TBI.
GOSE, Glasgow Outcome Scale-Extended; HRQoL, health-related quality of life; MCS, mental component summary; PCS, physical component summary; QOLIBRI-OS, Quality of Life after Traumatic Brain Injury overall scale; TBI, traumatic brain injury.

It is often suggested that patients with severe disability after TBI have lower self-awareness or anosognosia and a bias towards responding positively on outcome assessments.[14 38] This might explain, for example, positive ratings on the QOLIBRI-OS among more disabled individuals. Although impairments of self-awareness can be present after TBI, Sasse *et al*[38] found that the influence on reported HRQoL was weak. Furthermore, in our study, patients showed awareness of functional limitations on the PCS and nonetheless gave positive ratings of HRQoL on the MCS. The dissociation observed for two summary components of the same self-reported outcome appears to rule out an account in terms of global lack of awareness. That is, the discrepancy means that patients were not simply responding with positive ratings across all items, in a way that one might expect if the person had profound loss of awareness, and would imply that the responses were meaningless. Nonetheless, more selective limitations of awareness may play a role, for example, lack of awareness of cognitive impairment or mental health problems.[39] Alterations in awareness may thus contribute to discrepancies, and this deserves further study.

Besides deficits in general functional outcome cognitive impairments are likely to play a role in perception of well-being after TBI. A prior CENTER-TBI study found that MCS scores generally decreased with increasing cognitive impairment and apparently reached a plateau in the severely disabled group.[37] Cognition may play a number of different roles, and it is possible that cognitive impairment has some protective role in the most severely disabled patients.[38] Data on cognitive impairments from severely disabled patients (GOSE 3–4) were too limited to allow us to examine this issue, and it remains an important topic for future research. Furthermore, prevalence of cognitive impairment is likely to be a key difference between the two severity groups that we studied.[40] Notably, discrepancies were observed in both groups and were not more pronounced in more severely injured patients than the group with mild injuries.

Following TBI, disability is often assessed using functional outcome scales such as the GOSE. The SF-12v2 and QOLIBRI-OS also try to capture the patient's subjective experience of their well-being in daily life.[7] Decisions about the management of TBI are sometimes founded on the likelihood of the person remaining dependent, under the assumption this will lead to impaired HRQoL, and therefore classified as an 'unfavourable' outcome. In contrast, our findings showed that HRQoL does not simply follow functioning. Our results thus represent a strong caution against adopting a negative view of potential HRQoL and well-being in patients who are severely disabled based on the GOSE.

We found the lowest levels of HRQoL in patients with moderate disability. Similarly, in a study of patients after severe TBI, Mailhan and colleagues[35] found the lowest level of life satisfaction in patients with moderate disability, which they attribute to lower satisfaction in the domains social and family life. Our results also indicated that patients with moderate disability might be less satisfied with their social support and were less likely to receive rehabilitation. As expected, access to rehabilitation services is more likely among patients following moderate and severe TBI and patients with severe disability compared with their respectively less severely injured and disabled counterparts.[41] A previous study showed that patients after less severe TBI report more unmet rehabilitation needs than those following severe TBI.[42] Patients with moderate disability are independent, but are unable to return to work, and experience activity limitations.[20 43] Although these patients experience activity limitations, the injury and its consequences might be less visible to their environment compared with patients with severe disability, which could result in less (social) support. To be unable to work and be isolated in the community, may well be worse for well-being than being dependent in daily life but well-supported by others. Our results thus suggest that patients with lower moderate disability living in the community should be a particular target for additional support, rehabilitation and interventions. Furthermore, as perceptions of well-being are often discordant with disability level following TBI, recovery should be based on a multidimensional outcome measure including disability on multiple domains including physical, cognitive and social disabilities and HRQoL.

The disability 'paradox' has more than once been described as good well-being 'against all odds', implying that physical disabilities are the main driver of well-being.[11] However, we found that personal, injury-related and environment factors explain a proportion of HRQoL outcomes beyond functional outcome. Nevertheless, only up to 29% of the variance in QOLIBRI-OS and 21% of the variance in MCS was explained by GOSE, personal and injury-related characteristics and satisfaction with social support. Furthermore, personal, injury-related and environment factors did not explain the discrepancies between the GOSE and HRQoL in patients following mild TBI. Injury-related factors included MEI, which is known to have a dominant effect on outcome after mild TBI.[31] As the majority of variance remained unexplained, future research should consider the effect of coping, resilience, adaptation and cognitive impairments on HRQoL following TBI. To further explain HRQoL in patients following TBI, it is crucial to involve patients and their relatives. The focus on mixed methods research, combining quantitative and qualitative methods, might help to elucidate patients' perceptions of satisfactory quality of life following TBI.

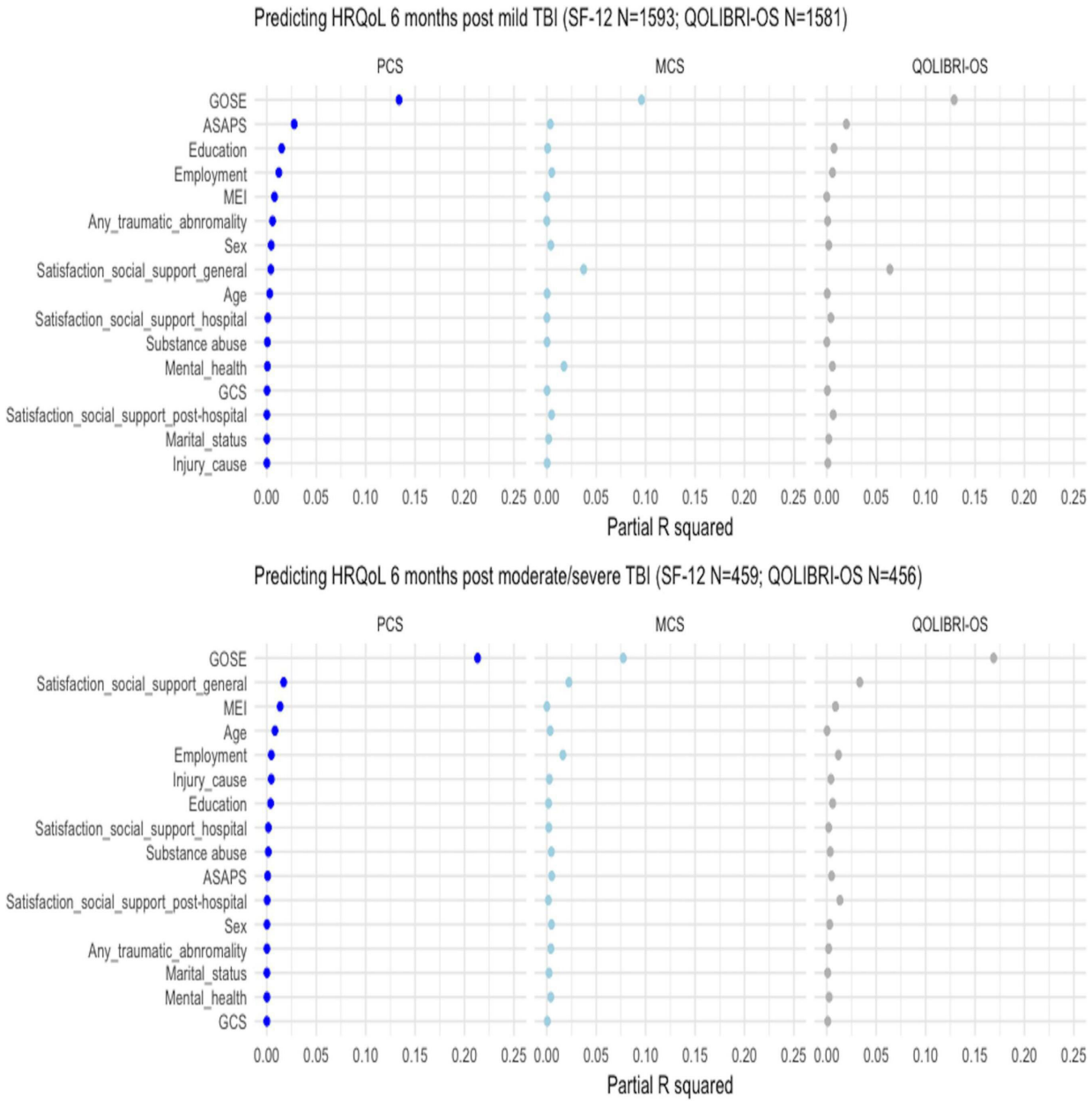

Figure 2 Contribution of predictors to explained variance (partial R^2) of the models for SF-12 PCS (left), SF-12 MCS (middle) and QOLIBRI-OS (right). The partial R^2 is calculated as follows: total R^2 of multivariable model – R^2 multivariable model without individual predictor: total R^2 of multivariable model without individual predictor=partial R^2. MCS, mental component summary; PCS, physical component summary; QOLIBRI-OS, Quality of Life after Traumatic Brain Injury overall scale.

Strengths

The strengths of this study include the use of data from a large international, multicentre observational study. Consequently, we made use of a standardised collection of data and a well described and contemporary cohort of patients. Furthermore, the CENTER-TBI study enrolled patients following mild, moderate and severe TBI, which enabled us to compare HRQoL outcomes by injury severity. Moreover, to describe HRQoL following TBI, we used generic (SF-12v2) and disease-specific (QOLIBRI-OS) instruments. The combination of generic and disease-specific instruments has been recommended to more fully capture patients' HRQoL following TBI.[7] Furthermore, we demonstrated the dissociation between physical and mental HRQoL using two scales from the same instrument, arguing against the idea that the discordance results from compromised self-awareness following TBI.[12 13]

Limitations

Several limitations of our study have to be considered. Patients with lower functional outcome on the GOSE and lower HRQoL were less likely to complete the questionnaires, potentially resulting in a response bias. Furthermore, the SF-12v2 is not suitable for patients with major cognitive impairment or language difficulties. Thus, the most severely disabled patients, who are likely to be among the most distressed, are not represented in the data. Taken together, the results of our study can only be generalised to patients who are able to respond to follow-up questionnaires, implying that our findings will not apply to a subgroup of

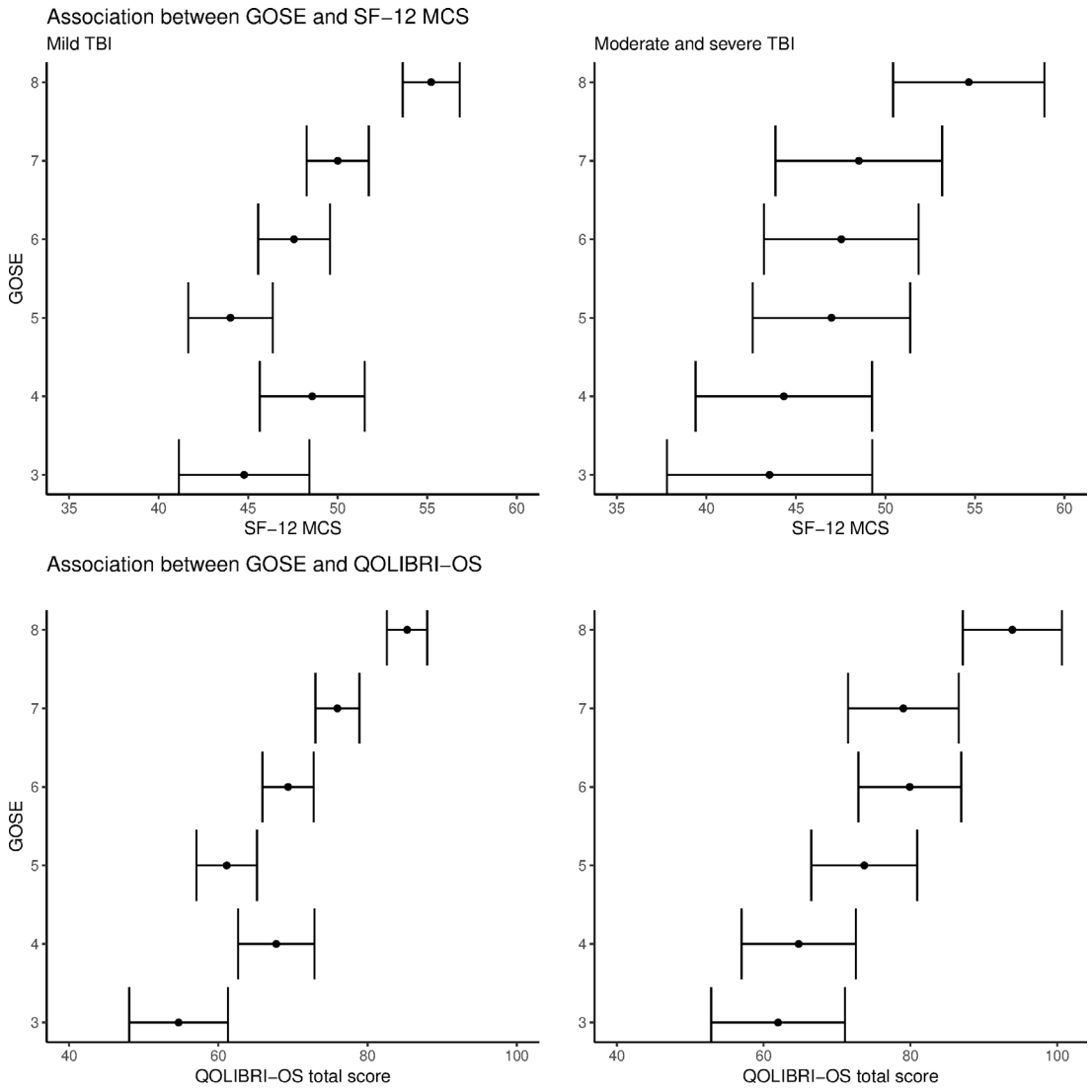

Figure 3 Adjusted association between the GOSE and the SF-12 MCS (upper) and QOLIBRI-OS (lower) for the 'average' patient (sex=male; age=51; marital status=married; highest level of education=second/high school, type of employment=working, preinjury mental health problems=no, preinjury substance abuse=no; preinjury health status (ASA-PS)=healthy; injury severity (GCS)=15; cause of injury=incidental fall; major extracranial injury=no; presence of intracranial traumatic abnormalities=present; satisfaction with social support=high; satisfaction with support from the hospital and health services=high; satisfaction with support from rehabilitation services=high). ASA-PS, The American Society of Anesthesiologists-physical status classification system; GOSE, Glasgow Outcome Scale-Extended; MCS, mental component summary; PCS, physical component summary; QOLIBRI-OS, Quality of Life after Traumatic Brain Injury overall scale; TBI, traumatic brain injury.

patients with profound disability, severe neurological problems, or language difficulties.

CONCLUSION

Our study confirms that patients' perceptions of HRQoL are often discordant with level of disability following TBI. Contrary to the idea that discrepancies are unusual, many patients with poor functional outcomes report satisfactory well-being, particularly in patients after mild injury. These results indicate that the effects of 'mild' TBI can be extensive and warrant further investigation. Furthermore, the findings challenge the idea that good quality of life in patients with disability should be described as 'paradoxical' and question common views of what constitutes 'unfavourable' outcome.

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Ethics approval The CENTER-TBI study (EC grant 602150) has been conducted in accordance with all relevant laws of the EU if directly applicable or of direct effect and all relevant laws of the country where the Recruiting sites were located, including but not limited to, the relevant privacy and data protection laws and regulations (the 'Privacy Law'), the relevant laws and regulations on the use of human materials, and all relevant guidance relating to clinical studies from time to time in force including, but not limited to, the ICH Harmonised Tripartite Guideline for Good Clinical Practice (CPMP/ICH/135/95) ("ICH GCP") and the World Medical Association Declaration of Helsinki entitled 'Ethical Principles for Medical Research Involving Human Subjects'. Informed Consent by the patients and/or the legal representative/next of kin was obtained, accordingly to the local legislations, for all patients recruited in the Core Dataset of CENTER-TBI and documented in the e-CRF. 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