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Time to surgery and postoperative functional outcomes among patients with chronic subdural haematomas

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ABSTRACT

Background Chronic subdural haematoma (cSDH) is a common neurological condition. Surgery remains the preferred treatment for symptomatic patients. Delays in surgery can occur due to logistical, clinical or medication-related factors. We investigated the relationship between time to surgery and postoperative functional outcomes in symptomatic cSDH.

Method Retrospective multicentre cohort study conducted from 2012 to 2023 across five UK neurosurgical units within the National Health Service system, with 1-year follow-up. Of the 1508 patients referred for surgical intervention for cSDH, 1015 remained for analysis. 213 were excluded due to missing data and 280 for ≥30-day wait for surgery to mitigate extreme outliers. Postoperative functional outcome was assessed using the modified Rankin Scale, categorised as 'favourable' (0–3) and 'unfavourable' (4–6). Predictors of outcome were identified using multivariable logistic regression, and the association between time to surgery and outcome was evaluated by marginal effects analysis. Factors influencing time to surgery were analysed by multivariate linear regression.

Results Of 1015 patients, 838 (82.6%) had 'favourable' outcomes and 177 (17.4%) had 'unfavourable' outcomes. Surgical delay was significantly longer in patients with 'unfavourable' outcomes (mean 4.4 vs 2.9 days, p<0.001) and independently associated with poorer outcomes (OR=1.05 per day, p=0.002). Risk increased linearly for each additional day of delay, up to 28% by day 30. Delayed time to surgery included older age (p=0.007), antiplatelet use (p<0.001), high Glasgow Coma Scale Score and Low Frailty Score.

Conclusion Surgical delay significantly worsens outcomes in cSDH. Older age, antiplatelet therapy, milder neurological presentation and low frailty scores were key contributors to delay.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous studies investigating the impact of surgical delay in chronic subdural haematoma (cSDH) have produced mixed results. Some report no difference when surgery is delayed up to 24 hours or even 3 days, while others suggest worse outcomes beyond 7 days. Most prior analyses used small samples, categorical delay groups or arbitrary cut-off points, limiting statistical power.

WHAT THIS STUDY ADDS

⇒ To the best of our knowledge, this is the largest multicentre cohort of symptomatic cSDH to date. We show that surgical delay is independently and significantly associated with poorer functional outcomes, increasing with each day that surgery is delayed. Older age, antiplatelet therapy and better neurological status were key drivers of delay.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ These findings support prioritising timely surgery for patients with symptomatic cSDH, as even short delays can negatively impact functional recovery. They also highlight the need to re-evaluate triage practices that defer surgery in patients with milder neurological symptoms or those receiving antiplatelet therapy. Furthermore, the results encourage the development of streamlined care pathways and risk-stratification tools to ensure timely surgical intervention and optimise outcomes across neurosurgical units.

INTRODUCTION

Chronic subdural haematoma (cSDH) is the collection of blood and blood-degradation products

in the subdural space between the dura mater and arachnoid layers of the brain, typically from minor head trauma and likely sustained by chronic inflammation.[1] While initial symptoms are usually mild, progressive fluid accumulation and raised intracranial pressure can lead to headaches, cognitive impairment and unsteady gait, followed by focal neurological deficits such as hemiparesis and aphasia.[2] The incidence of cSDH is high, with 5000 people aged over 65 being diagnosed each year in the UK.[3] Patients are commonly from the elderly population, particularly with pre-existing comorbidities or who are taking antithrombotic medications.

Management of cSDH is based on the severity of neurological symptoms and/or radiological scans. Asymptomatic or mildly symptomatic patients are usually managed conservatively, while those with severe symptoms or large haematomas are offered surgical treatment. Middle meningeal artery (MMA) embolisation may also be offered for mild-to-moderate presentations, or in combination with surgery in refractory cases to prevent recurrence.[4] Common surgical approaches include twist-drill craniostomy, borehole craniostomy and minicraniotomy.[5] Several large-scale studies, such as the drain-versus-no-drain randomised controlled trial by Santarius *et al*,[6] the Dexamethasone for Adult Patients with a Symptomatic Chronic Subdural Haematoma (Dex-CSDH) trial [7] and the cSDH-Drain-Trial,[8] have helped define surgical techniques and perioperative management. Multiple factors influence time to surgery for cSDH, such as clinical judgement, logistical factors such as theatre availability and resource constraints, and whether the patient is on antithrombotic medications. Additionally, not all tertiary centres and hospitals provide access to neurosurgery; in these cases, inter-hospital transfer is required, and this decision is dependent on factors such as age and radiological findings.[9]

Nevertheless, the role of time from referral to surgery on patient outcomes remains unclear, as previous studies involving small patient cohorts, often from single-centre experiences, highlighted conflicting results. This study aims to investigate the relationship between time to surgery and postoperative functional outcomes of patients with symptomatic cSDH within a hierarchical multicentre network as the National Health System (NHS), accounting for key covariates such as age, frailty and preoperative neurological status.

METHODS

This multicentre retrospective cohort study was conducted in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for retrospective observational studies.[10] The study was registered with the respective hospitals, and compliance with the General Data Protection Regulation was ensured.

Study population

The study was conducted across five neurosurgical units in the UK. All patients referred for surgery for cSDH from January 2012 to March 2023 were reviewed. Eligibility criteria were confirmed cSDH based on CT and/or MRI. Patients treated conservatively or with medical management only were excluded. No patients in this study underwent MMA embolisation.

The data collection and analysis process are summarised in figure 1. Of the initial 1508 patients, 213 were excluded due to missing data. An additional 280 patients who waited ≥30 days from referral to surgery were excluded to mitigate extreme outliers. Final analysis included 1015 patients. Missing data were presumed to be missing completely at random except for the postoperative functional outcome at follow-up (n=25, 1.7%), which could be missing due to poor outcomes.

Identifying predictors of functional outcome by multivariable logistic regression

Electronic medical records were retrospectively reviewed for demographic data, clinical data and radiological evaluations. Postoperative functional outcome was assessed based on the modified Rankin Scale (mRS) for follow-up of 1 year. Where not available, mRS at discharge was considered using the

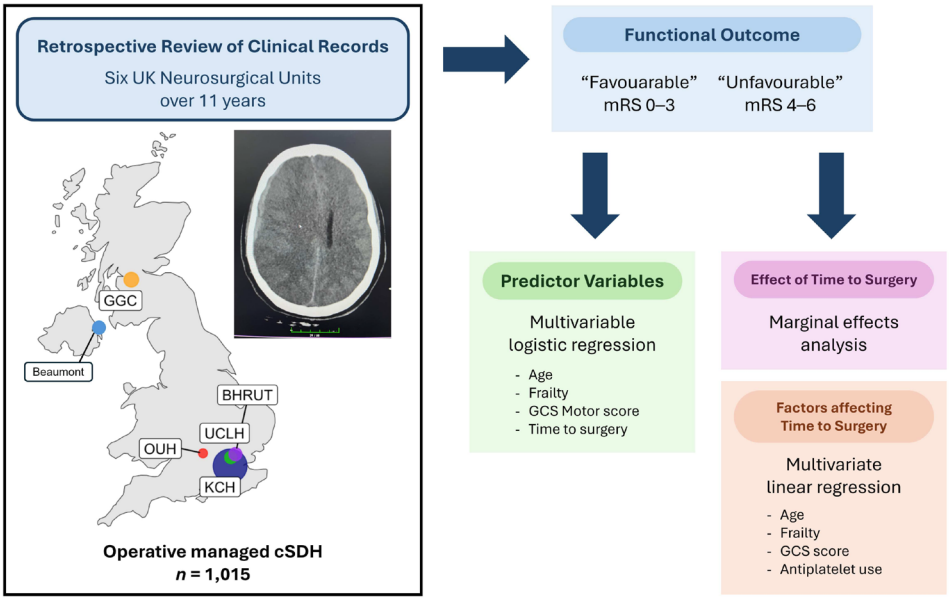

Figure 1 Summary of patient inclusion, data collection and analysis. cSDH: chronic subdural haematoma; mRS: modified Rankin Scale; GCS: Glasgow Coma Scale; KCH: King's College Hospital; UCLH: University College London Hospitals; OUH: Oxford University Hospitals; BHUT: Barts Health NHS Trust; GGC: NHS Greater Glasgow and Clyde.

last-carried forward method. mRS scores were categorised as 'favourable' (0–3) or 'unfavourable' (4–6), consistent with previous studies such as the Dex-CSDH trial,[7] the cSDH-Drain-Trial[8] and the randomised controlled trial by Schucht *et al*.[11] To ensure comparability, patients with baseline frailty that would preclude the possibility of achieving a 'favourable' outcome were excluded. This refers to patients with Rockwood Clinical Frailty Scale (CFS) Score≥5, as CFS 5 ('mildly frail: needs help with high-order activities of daily living') is most compatible with mRS 3 ('moderate disability: requires some help, but able to walk unassisted').[12 13]

Multivariable logistic regression was performed to model the probability of attaining an 'unfavourable' outcome. Predictor variables included age, frailty (CFS Score), Glasgow Coma Scale (GCS) Motor Score and time from referral to surgery (days). Continuous variables were modelled without categorisation. Gender was excluded from the final model after demonstrating no independent effect. The model had an Akaike information criterion (AIC) of 875, residual deviance of 865 and R^2 of 8.5%. Based on univariate analysis, variables with a p value<0.05 include cardiovascular disease (CVD), dementia, diabetes, anticoagulation and previous cSDH drainage. When these variables were added to the model, the overall fit improved, with reduced AIC of 725.5 and residual deviance of 703.5. However, this came at the cost of excluding 99 additional observations (9.8%) due to missing data. In a more parsimonious model including only dementia and CVD from this group, statistical significance was retained, but missingness still increased by 67 observations (6.6%).

To account for potential clustering of patients within hospitals, we fitted a mixed-effects logistic regression model including a random intercept for hospital site. We tested for possible interactions between age and time to surgery by including an interaction term (Age×time from referral-to-surgery) in the model.

Linear regression analysis was conducted on the full dataset, treating CFS score as a continuous variable to assess potential multicollinearity between age and frailty. Age and frailty showed a weak association (R^2=11.6%, p<0.001), justifying both inclusion into the model. Multicollinearity between covariates in the final model was assessed using the variance inflation factor (VIF). All VIF values were low (range 1.03–1.13), suggesting no significant multicollinearity.

Further, we examined the predictive value of GCS scores at referral. Of all components, GCS Motor Score was the strongest independent predictor of outcome (OR 0.53, 95% CI 0.43 to 0.65, p<0.001). GCS Eye (OR 0.62, 95% CI 0.51 to 0.74, p<0.001), Verbal (OR 0.62, 95% CI 0.54 to 0.72, p<0.001) and total GCS (OR 0.80, 95% CI 0.76 to 96, p<0.001) scores were also associated with outcome, but to a lesser degree. Thus, GCS Motor Score was included in the model.

Evaluating the effect of time to surgery on functional outcome by marginal effects analysis

A marginal effects analysis was performed to visualise the predicted probability of an 'unfavourable' outcome (mRS 4–6) with time to surgery, holding other covariates constant. Fixed covariate values representative of the cohort were mean age 72.4 years, CFS Score 5 and GCS Motor Score 6. Resulting predictions were plotted and tabulated with 95% CIs. The analysis was also performed within the subgroup of patients with only mild neurological impairment at presentation (GCS 13–15).

Table 1 Univariate comparison of patients with 'favourable' versus 'unfavourable' outcomes (mean (SD))

	Favourable	Unfavourable	P value
n	838	177	
Time to surgery (days)	2.9 (5.0)	4.4 (6.0)	**<0.001**
Age	71.5 (14.3)	76.7 (11.8)	**<0.001**
Male gender (%)	613 (73.2)	119 (67.2)	0.127
CVD (%)	180 (21.5)	60 (33.9)	**0.001**
HTN (%)	341 (40.7)	80 (45.2)	0.307
Anticoagulation (%)	155 (18.7)	48 (27.3)	**0.013**
Antiplatelet (%)	175 (22.6)	39 (26.5)	0.351
CKD (%)	62 (7.4)	20 (11.3)	0.114
Smoker (%)	188 (20.6)	58 (24.7)	**0.005**
Dementia (%)	65 (8.1)	32 (21.6)	**<0.001**
Diabetes (%)	185 (17.6)	71 (26.9)	**<0.001**
Hemiparesis (%)	292 (37.3)	68 (45.6)	0.068
Length of stay (days)	11.9 (137)	22.4 (26.3)	**<0.001**
GCS severity			
Mild (13–15)	772 (92.7)	144 (81.4)	**<0.001**
Moderate (8–12)	50 (6.0)	26 (14.7)	
Severe (<8)	11 (1.3)	7 (4.0)	
Operation type (%)			
Burrhole	747 (82.8)	155 (17.2)	0.637
Minicraniotomy	91 (80.5)	22 (19.5)	
Drain type (%)			**0.0431**
No drain	151 (89.3)	18 (10.7)	
Subdural	608 (82.1)	133 (17.9)	
Subgaleal	55 (78.6)	15 (21.4)	

Bold values indicate statistical significance (p < 0.05).
CKD, chronic kidney disease; CVD, cardiovascular disease; GCS, Glasgow Coma Scale; HTN, hypertension.

Identifying factors influencing time to surgery by multivariate linear regression

Finally, we used multivariate linear regression to model how variables influenced time to surgery. We assessed clinically important variables in a step-backwards method, resulting in age, GCS at referral, antiplatelet use and frailty. The model had a residual deviance of 854.6 and an AIC of 864.6. R^2 was 8.2%, indicating modest explanatory power.

Statistical analysis was performed using RStudio (V.4.4.1).

RESULTS

1015 patients were included in the final analysis. The mean age was 72.4±14 years, and the majority of participants were male (n=732). 838 (82.6%) achieved a 'favourable' outcome (mRS 0–3), while 177 (17.4%) achieved an 'unfavourable' outcome (mRS 4–6) (table 1).

Patients with an 'unfavourable' outcome were generally older (mean age 76.7 vs 71.5 years, p<0.001) and experienced longer delays to surgery (mean 4.4 vs 2.9 days, p<0.001). The comorbidities between groups were assessed by CFS score and overall demonstrated no differences (mean score 2.87 vs 2.98, p=0.348). However, some were more prevalent in the 'unfavourable' group, including CVD (p=0.001), smoking (p=0.005), dementia (p<0.001), diabetes (p<0.001) and anticoagulation therapy (p=0.013). Additionally, patients in the 'unfavourable' group experienced longer hospital stays (p<0.001).

Table 2 Multivariable logistic regression model for predictors of an 'unfavourable' outcome

	'Unfavourable' outcome (mRS 4–6)		
Predictors	**OR**	**95% CI**	**P value**
(Intercept)	0.56	0.12 to 2.60	0.454
Age	1.04	1.02 to 1.06	**<0.001**
CFS Score	0.86	0.76 to 0.97	0.011
GCS Motor Score	0.53	0.43 to 0.65	**<0.001**
Time to surgery (days)	1.05	1.02 to 1.08	**0.002**

Bold values indicate statistical significance (p < 0.05).
CFS, Rockwood Clinical Frailty Scale; GCS, Glasgow Coma Scale; mRS, modified Rankin Scale.

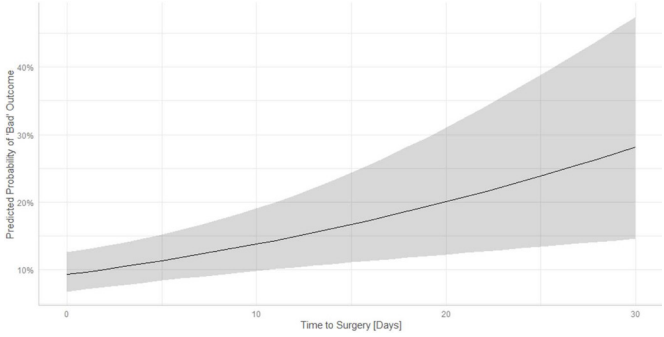

Figure 2 Marginal effects plot of predicted 'unfavourable' outcome probability against time to surgery.

The choice of surgical technique (burr-hole drainage or mini-craniotomy) was left to individual surgeon discretion based on local practice patterns and imaging characteristics. Most patients (88.9%, n=902) underwent burr-hole evacuation, while 11.1% (n=113) underwent minicraniotomy. Across the five units, burr-hole use ranged from 88.2% to 100% (p=0.195), indicating no statistically significant interunit variation.

Regarding drain use, 73.0% (n=741) had a subdural drain, 6.9% (n=70) a subgaleal drain and 16.7% (n=169) no drain (n=35 missing). Across hospitals, subdural drain use ranged from 66.7% to 82.4%, subgaleal drain use from 0% to 7.1% and no drain from 0% to 25.8% (p=0.905).

Age, time to surgery and preoperative neurological status are independently associated with worse functional outcomes

A multivariable logistic regression model was constructed to identify predictors of an 'unfavourable' outcome (mRS 4–6), using age, CFS Score, GCS Motor Score at referral and time to surgery (days) as independent variables (table 2). Age (p<0.001), time to surgery (p=0.002) and low GCS Motor Score (p<0.001) were independently associated with poorer functional outcomes. The association between time to surgery and outcome did not change significantly with patient age (OR=1.00, 95% CI 1.00 to 1.00, p=0.442).

To assess potential variations in outcomes between hospital sites, a mixed-effects model was generated with hospital site as a random intercept. The intraclass correlation coefficient was 0.00, suggesting no detectable variation between sites.

Increased time to surgery correlates linearly with worse functional outcomes irrespective of age, frailty and preoperative neurological status

Marginal effects analysis revealed that the risk of an 'unfavourable' outcome increases linearly for each additional day of delay, from 9% on day 0 (95% CI 7% to 13%) to 28% by day 30 (95% CI 15% to 47%). This is an average 0.6% increase per day, even after adjusting for age, frailty and GCS Motor Score (figure 2). Subgroup analysis restricted to patients with mild GCS scores (13–15) continued to show a similar linear association between longer time to surgery and poorer outcomes (online supplemental table 1).

Factors affecting time to surgery

To identify predicting factors associated with time to surgery, a multivariate linear regression model was generated with time to surgery (days) as the outcome (table 3). Antiplatelet therapy was the strongest modifiable factor, with patients on antiplatelets experiencing a mean delay of 1.86 days. While median time to surgery was 1.0 days in both groups, mean time was longer for those on antiplatelets (4.36±6.21 vs 2.64±4.70 days). A density plot revealed a noticeable shift, with more patients on antiplatelets undergoing surgery 7–10 days after referral. Age had a limited effect on time to surgery, with each additional year associated with a 0.03 day increase in time to surgery (p=0.007), but with minimal effect size. Better neurological status and lower frailty were also associated with delayed surgery, with a 0.33-day increase and 0.28-day reduction in time to surgery per 1-point increase in GCS and CFS scores, respectively.

Time to surgery and postoperative complication rates

The overall postoperative complication rate was 19.1% (n=194), with rates across hospitals ranging from 16.1% to 33.3% (p=0.60). Using complications as a binary outcome (yes/no) in a logistic regression model, adjusting for age, frailty and GCS Motor Score, each additional day from referral to surgery was associated with a 4% increase in the odds of developing a postoperative complication (OR 1.04, 95% CI 1.01 to 1.06; p=0.014; R^2=5.6%). Although this finding reached statistical significance, the effect size and model explanatory power were both small, indicating that time to surgery explains little of the variation in complication rates. Consequently, it is unlikely that in-hospital complications mediated the observed association between surgical delay and worse functional outcomes.

DISCUSSION

This study shows an association between increased time to surgery and a higher risk of unfavourable functional outcomes in cSDH patients. A linear relationship was observed, with each additional day of delay linked to a 0.6% increase in risk of poorer outcomes. Older age, antiplatelet use, higher GCS and

Table 3 A multivariable linear regression model with time to surgery (days) as an outcome

	Time to surgery (days)		
Predictors	**Estimates**	**95% CI**	**P value**
(Intercept)	−3.43	−6.38 to −0.48	**0.023**
Age	0.03	0.01 to 0.06	**0.007**
GCS total	0.33	0.16 to 0.50	**<0.001**
Antiplatelet	1.86	1.17 to 2.55	**<0.001**
CFS Score	−0.28	−0.47 to −0.09	**0.003**
R^2			5.2%

Bold values indicate statistical significance (p < 0.05).
CFS, Rockwood Clinical Frailty Scale; GCS, Glasgow Coma Scale.

lower frailty scores at referral were associated with longer delays to surgery.

Timely surgery is a recognised determinant of outcome in other common conditions affecting older adults, notably neck of femur (NOF) fractures. Evidence from national audits and randomised studies demonstrated that delays to surgery beyond 24–48 hours are associated with increased mortality, postoperative complications and extended hospital stays for hip fractures.[14 15] These findings have led to establishing time-to-surgery benchmarks in orthopaedic guidelines, such as those from the National Institute for Health and Care Excellence in the UK,[16] and a best practice tariff of joint care under orthopaedics and geriatrics. Given the similarities between NOF fracture and cSDH populations, such as advanced age, frailty and risk of functional deterioration, there is strong rationale for investigating whether early surgical intervention may similarly improve outcomes in cSDH.

In this study, we showed that delays to surgery are significantly associated with poorer outcomes for cSDH. Marginal effects analysis revealed a clear linear increase in risk of poorer outcomes with each additional day of delay for the first 30 days (0.6% per day, figure 2). This trend persisted even after adjusting for other risk factors such as age, frailty and GCS Score, and remained significant among patients with only mild neurological impairment (online supplemental table 1). We excluded extreme surgical delays (>30 days) from our analysis to minimise the impact of outliers and focus on clinically actionable time frames.

Previous studies on surgical delay and outcomes reported mixed findings. Venturini *et al* and the British Neurosurgical Trainee Research Collaborative retrospectively analysed 656 out of 1205 patients to examine the association between poor outcomes (mRS 4–6) and surgical timing using ordinal categories (0, 1, 2, 3–6 and ≥7 days).[17] Their findings suggested that a delay of ≥7 days reduced the odds of favourable outcomes at discharge; however, the trend was non-significant (p=0.061). The authors acknowledged a risk of type 2 error due to the smaller sample size and categorisation of the surgical timing variable. Indeed, dichotomising continuous variables may lead to substantial loss of information, reduced ability to detect true effects and increased risk of misleading results due to arbitrary cut-points.[18 19]

Foppen *et al* studied 330 patients with mild-to-moderate cSDH[20] and reported that time to surgery within or after 24 hours did not affect clinical outcomes, suggesting that postponing surgery to daytime hours may be safe for mild/moderate cases, while Colonna *et al* reported significantly better outcomes for surgeries within 3 days.[21] Taken together, it would appear that deferring surgery to daytime hours is safe within a 3 day time window. However, our data established a cumulative and linear correlation between surgical delay and poorer outcomes even within the first 3 days. It is therefore recommended that patients with symptomatic cSDH should be scheduled for surgery as early as possible during daytime hours to minimise risk, rather than being delayed to the end of the list.

Alongside time to surgery, age and GCS Motor Score at referral also independently predicted outcomes (table 3). Notably, GCS Motor Score was a stronger predictor than total GCS Score. This finding aligns with the well-validated International Mission for Prognosis and Analysis of Clinical Trials in TBI (IMPACT) Score for Outcomes in Head Injury.[22] A recent single-centre study by Zolnourian *et al* similarly identified GCS Motor Score to significantly predict outcomes following burr hole drainage surgery for cSDH, including Glasgow Outcome Scale Score, odds of home discharge, postoperative complications and length of hospital stay.[23]

While age is commonly included in prognostic models, frailty (CFS Score) provided additional explanatory value. We excluded patients with baseline frailty unlikely to recover well (CFS≥5) to maintain clinical relevance and comparability with prior studies. Indeed, it is well established that reduced frailty and early mobilisation improve outcomes by enhancing functional recovery, reducing hospital stay and minimising complications.[24] In cSDH, the GET-UP trial demonstrated that early mobilisation reduced complication rates. Additionally, delayed surgery may prolong the duration of mass effect on the brain, impairing recovery over time.[25] Our data likewise showed that longer hospital stay was associated with poorer outcomes (table 1).

Our mixed-effects model revealed minimal outcome variation between hospital sites, suggesting institutional practice or resource differences did not significantly influence results. This is expected as all institutions in this study practise within the NHS setting, with standardised referral systems across the multilayered network. Our findings therefore support generalisability across institutions and reinforce the role of individual clinical factors over system-level variation.

Surgery for cSDH may be delayed in practice for various reasons, such as antiplatelet treatment.[26] Guidelines from the International Anaesthesia Research Society recommend discontinuing clopidogrel and aspirin 7 days before surgery, and at least 3 days for emergencies, to allow partial restoration of platelet function.[27 28] Supporting this, level III evidence suggested that a 3-day delay may be sufficient to reduce recurrence in cSDH.[29] In our study, antiplatelet use was associated with longer delays to surgery, likely due to the required discontinuation period. Nevertheless, a recent randomised clinical trial found that discontinuing aspirin did not significantly reduce 6-month recurrence risk, and continued use posed less risk than previously reported,[30] suggesting that the benefits of delaying surgery to discontinue antiplatelet therapy may be overstated for cSDH. In contrast, anticoagulation use was associated with poorer outcomes (table 1), possibly due to the nature of anticoagulation leading to greater impairment of the clotting cascade. Current perioperative reversal strategies include vitamin K and prothrombin complex concentrate for anticoagulants and intraoperative platelet infusion for antiplatelets, although recent preliminary evidence suggests that platelet infusion may not be as effective at reversing antiplatelet effects as previously assumed.[31] Nevertheless, these measures should still be considered to minimise surgical delays and enhance safety.

Alongside antiplatelet treatment, patients with milder GCS severity at referral also waited longer for surgery (table 3), likely reflecting clinical triage of neurologically intact patients as lower priority. However, even within this subgroup, the linear relationship between time to surgery and poor outcomes persisted (online supplemental table 1). This suggests that deferring surgery in patients who appear neurologically 'well' may not be justified. Frailer patients experience shorter delays, likely due to earlier presentation, triage bias and heightened urgency from referring clinicians.

Limitations and strengths

The study's retrospective design introduces inherent limitations, including selection bias and reliance on accuracy and completeness of routine clinical data. Additionally, mRS scores were not consistently recorded at follow-up; where unavailable, we used mRS at discharge as a last-observation-carried-forward proxy. This approach, while pragmatic, may underestimate late recovery or deterioration. We dichotomised the mRS into 'favourable' (0–3) and 'unfavourable' (4–6) outcomes, in accordance with prior

studies. Although this may obscure subtle outcome differences and reduce statistical power, it aligns with established thresholds for minimal clinically important differences, allowing for meaningful interpretation of functional outcomes in routine clinical practice.

Despite adjusting for key predictors such as age, frailty and neurological status, residual confounding from unmeasured variables such as haematoma volume, radiological features or perioperative care practices may persist. Excluding patients with baseline frailty scores≥5 improves relevance for the treatment-eligible population, but limits generalisability to frailer patients or those managed non-operatively. Additionally, the logistic regression model's low R^2 value (table 2), and the similarly weak linear regression model (table 3), suggest that variation in outcomes and time to surgery may be driven by other system-level factors such as hospital workload, theatre and bed status availability, referral timing (days of the week, period of the month or year) and social circumstances.

Nevertheless, our results provide strong evidence that, within a complex, multilayered neurosurgical referral system such as the NHS, increased time from referral to surgery is linked to poorer outcomes in cSDH patients. Given the consistency across hospitals, these findings are likely generalisable and reflective of real-world, multicentre practice. In this context, where randomised controlled trials would be ethically inappropriate due to the impossibility of justifying deliberate surgical delay in acutely presenting patients, this study offers valuable observational evidence. We believe these results should inform neurosurgical practice and support efforts to minimise the interval between referral and surgery in patients with cSDH.

CONCLUSIONS

In this multicentre retrospective cohort study of cSDH patients, increasing delay from referral to surgery was independently associated with worse functional outcomes, even after adjusting for age, preinjury frailty and neurological status on admission. Each additional day of delay was associated with a rising probability of poor outcome (0.06% per day). This study supports prioritising early surgery in symptomatic cSDH. Even though older age, antiplatelet medication, less severe neurological presentation and lower frailty scores were the main factors related to surgical delay in this study, further prospective studies are warranted to explore causality and assess whether system-level changes to streamline referral-to-surgery pathways can yield clinically meaningful benefits.

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