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Determining the appropriate use of Technology Enabled Care Services (TECS) to manage upper-limb trauma injuries during the COVID-19 pandemic: A multicentre retrospective observational study

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Summary Background: The COVID-19 pandemic created a unique opportunity to explore the use of Technology Enabled Care Services (TECS), which remains novel for many service providers. This study assesses the factors that affect adaptation to remote monitoring of patients after upper-limb trauma injury. A standardised risk-stratified screening tool is further developed here to support clinical staff in both the determination of appropriate use of TECS and the optimisation of patient care.

Objectives: 1: To explore the patient and injury factors that determine the appropriate use of TECS for patients with upper-limb injury. 2: To use these findings to refine a standardised screening tool for the appropriate choice of follow-up format.

Methods: A retrospective review of patient management was undertaken across three NHS upper-limb trauma units during the first UK COVID-19 lockdown. Data were collected, and themes were analysed across a number of predetermined categories. This was underpinned by a review of contemporary policy guidance and literature.

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Results: A total of 85% of patients were offered an appropriate format of follow-up; this was defined by the ability to achieve desired patient-clinician goals and lack of complications. Key factors in determining appropriate follow-up included extent of injury, mental health considerations, and the need for face-to-face (F2F) assessment and treatment.

Conclusion: Study findings demonstrate consistency between units in the factors determining the appropriate use of TECS. The refined screening tool provides a risk-stratified, standardised approach to the choice of follow-up format, F2F or TECS. It is hoped that this will support future clinical decision-making processes to ensure optimal patient care.

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Introduction

Digital transformation, including Technology Enabled Care Services (TECS), forms an essential component of the NHS Five-Year Forward View and the NHS Long-Term Plan.^{1,2} TECS utilises audio-visual technology, digital photography, and telecommunication. It has long been debated as a safe, cost-effective, and reliable means of delivering healthcare services.

The rapid acceptance and implementation of TECS were driven by the COVID-19 pandemic to limit face-to-face (F2F) contact and reduce disease transmission. This created a unique opportunity to evaluate how TECS is used to support the remote monitoring of patients presenting with acute upper-limb trauma injury.

A survey exploring the experience of 51 UK-based hand units revealed that 82% of respondents used TECS to manage upper-limb trauma during the first UK COVID-19 lockdown (23/03/20–10/05/20).³ An international cross-sectional survey involving hand surgeons and therapists reported that, before the pandemic, only 4% of respondents used TECS on a daily basis. This rose to 36% during phase one of the pandemic.⁴

An extensive qualitative literature explores the effective use of TECS in general practice,⁵⁻⁷ chronic musculoskeletal pathologies,⁸⁻¹⁰ and plastic surgery.^{11,12} Overall, patient satisfaction is high, and consultation waiting times are lower. TECS is considered cost-effective and accessible for patients with disabilities, care responsibilities, and prolonged travel times. Common concerns and study limitations included technological problems, increased consultation duration, and limited accuracy in physical examination. A gap in the literature exists as to the use of TECS in the follow-up of acute upper-limb trauma.

The primary objective of this study was to explore the decision-making process when determining the appropriate use of remote monitoring for patients with upper-limb trauma. A multicentre observational study was designed to capture demographics, psychosocial factors, extent of injury and treatment, hand therapy input, as well as the number and format of follow-ups provided.

The secondary objective was to utilise these data to evaluate and refine a risk-stratified screening tool to aid clinical decision-making in determining the appropriate use of TECS.³ A review of contemporary policy guidance and literature was performed to further inform this study.

It is proposed that this screening tool could be developed to justify service provision and aid workforce planning, as

well as to optimise patient care. It could then form part of national guidance on optimal, remote care for the management of upper-limb trauma injury.

Methods

Data collection

Anonymised data were collected retrospectively, as described in [Figure 1](#), from three upper-limb trauma units in the south of the United Kingdom (UK) during phase one of the COVID-19 response. Patients first presenting with upper-limb injury from 23/03/20 to 10/05/20 were included. Burns and chronic pathologies were excluded. Pre-populated data criteria were used to ensure consistency and completeness of data collection. Data included the format of follow-up, patient demographics, comorbidities, injury details, hand therapy input, and clinical decision-making and complications. The mechanism of injury was recorded, as well as structures injured and/or repaired. The data were analysed to interrogate any correlation between the format of each follow-up and these patient/injury factors. The chi-squared test was used for statistical analysis with a significance level of $p < 0.05$. Key themes from this analysis, alongside a literature review, informed the refinement of the risk-stratified screening tool.

Risk stratification

For the purpose of risk stratification for the need for F2F follow-up, a scoring system was adopted. A number of injured structures that were repaired were allocated 1 point; structures not repaired/treated were not counted. Each fracture was allocated one point irrespective of their management, conservative or surgical. Multiple structure injuries resulting in the terminalisation of a digit were not scored as a structural injury but allocated as wound risk. Similarly, simple soft-tissue injuries/infections were also allocated under wound risk [Table 1](#). describes the scoring for the number of structures requiring treatment and categorisation of structure according to risk. High-risk wounds were classed as complex wounds, terminalisations, contaminated/infected, or those requiring grafts/flaps. Any wound after intervention was categorised as moderate risk, and simple/clean wounds were categorised as low risk.

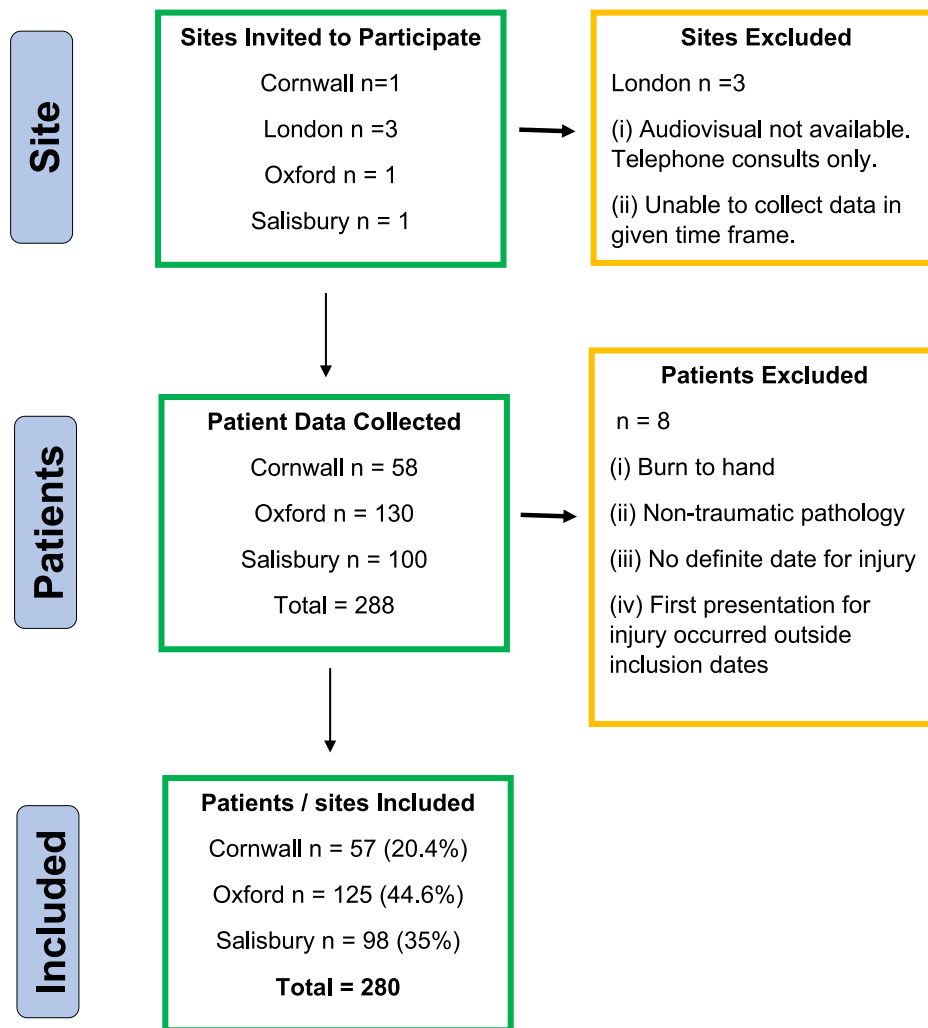


Figure 1 Number of sites and patients included and excluded from the study.

Results

Of the 288 cases recorded, 280 patients met the study inclusion criteria as described in Figure 1; Royal Cornwall Hospital ($n=57$), Oxford University Hospitals ($n=125$), and Salisbury District Hospital ($n=98$).

Demographics

More than twice as many males (69%) were recorded. Age was categorised into 10-year bands, and the median age range was 31-40 years. About 67% of patients identified as White British, 20% as an ethnic minority, and 13% did not state ethnicity. This compares with the 2011 UK census; 86% White British and 14% other ethnicities.¹³ The geographical coverage and specification of units are shown in Figure 2.

Comorbidities

Pre-existing hand pathology was recorded, as well as number of comorbidities. About 12% of patients presented with a

pre-existing hand pathology. About 66% had ≤ 1 comorbidity, 17% had ≥ 2 comorbidities, and 17% were not documented.

Psychosocial factors

Employment was categorised into administrative (86 patients, 31%), manual workers (140, 50%), and "not documented" (54, 19%). Higher injury complexity was more common in manual workers, with 11% (15/140) requiring treatment to >3 structures versus 8% (7/86) in the administrative group. The difference is not statistically significant ($p=0.53$). The manual workers required a greater proportion of F2F appointments, 231 (51%) F2F compared with 242 (49%) TECS. Administrative workers were more frequently seen remotely, 234 appointments (63%) vs 138 (37%) F2F. This difference is statistically significant ($p=0.0001$).

Caregiver Responsibilities: 30 patients (11%) had documented caregiver responsibilities. For this cohort, TECS was favoured over F2F appointments (57%, 17/30 vs 43%, 13/30).

Mental Health: About 31 patients (11%) had a pre-existing mental health diagnosis, 8 of which had poorly managed mental health. The average number of follow-ups was

Table 1 Scoring for the number of structures requiring treatment and categorisation according to risk.

Structures injured by groups	Score (Number of structures injured)	Risk Category Structure
Tendon	Score 1 point for each laceration in tendon that has been repaired.	High
Fracture	Score 1 point for each fracture within any given bone.	Low—simple/undisplaced Moderate—requires fixation High—complex
Infection	Score 0 for simple infection. Score 1 if joint/bone/flexor sheath	High
Ligamentous (Volar plate/ligaments)	Score 1 point for each structure treated	Moderate
Multiple structure (Injury > 1 different structure.)	Score 1 point for each structure treated.	Low ≤ 1 Moderate 2 High ≥ 3
Nerve	Score 1 point for each structure treated.	High
Simple skin/soft tissue	0	Low
Nail bed	Score 1 point for each nail bed treated.	Moderate
Soft tissue requiring reconstruction	Score 1 point for each structure reconstructed.	High

Note: Only structures repaired or that require splinting are included in count. E.g, Bony avulsions not counted as a fracture unless they require fixation.

There is no structural count allocated to a terminalized digit because the structures are not repaired. It will be included in wound risk.

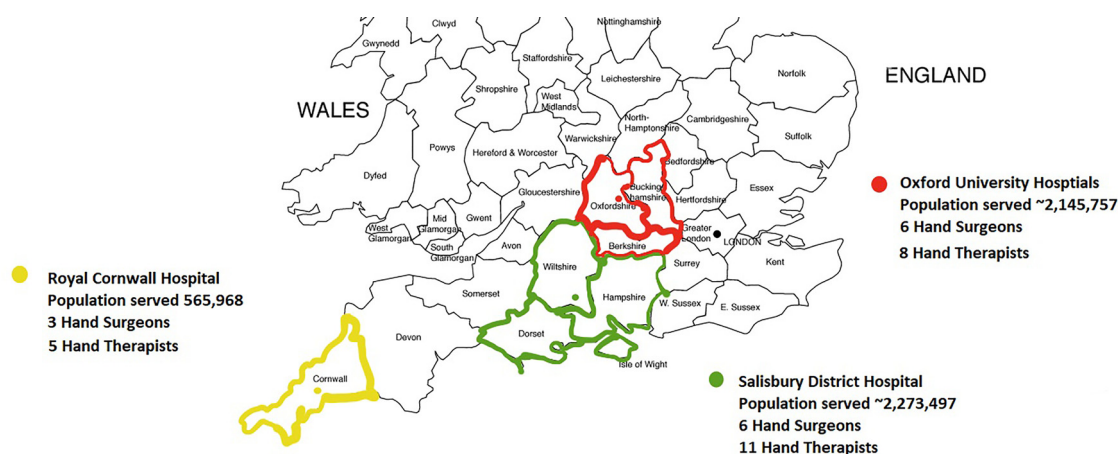


Figure 2 The geographical coverage, population served, and specification of units.

similar for all mental health patients. For poorly managed patients, more F2F contact was required as a proportion of follow-ups (66%) compared with the well-managed group (40%). There were insufficient data to test for statistical significance.

Extent of injury

Mechanism of injury: The most common mechanisms of injury were falls (21%), power tools (11%), crush injuries (11%), and hand tools (9%).

Hand dominance: About 54% of patients sustained injuries to the non-dominant hand and 44% to the dominant hand. About 3 patients (1%) sustained injuries bilaterally, and 2 patients (1%) were not documented. Injury to the

dominant hand did not correlate with the format of follow-up.

Number and type of structures: Approximately 252 (90%) patients had ≤ 2 structures repaired, and 28 (10%) had ≥ 3 . The latter had almost double the number of follow-ups compared with ≤ 2 structures (5.9 vs 3.1). As a proportion of follow-ups, they had more F2F contact (58% vs 44%). This was statistically significantly different ($p = 0.005$)

Skin/soft-tissue injuries were most prevalent (23%), followed by single bone fractures (19%) and multiple different structures (14%). Although soft-tissue injuries required the least mean number of follow-ups (1.2 sessions), they had a high rate of F2F contact (63% F2F vs 37% remote). The rate was similar for infection (62% F2F vs 38% remote).

High-risk injuries such as extensor/flexor tendons, peripheral nerve injury (PNI), multiple fractures, and injuries

Table 2 Reasons why patients were offered or declined face-to-face or remote contact.

	Face-to-face follow-up	Remote follow-up
Clinician reasoning behind offering:	Wound/infection review Change of dressing Splinting Hand therapy Removal of sutures Complex injury Ongoing pain Requiring psychosocial support	Simple wound Monitor progress Travel restrictions Elderly (COVID risk) Co-morbidities (COVID risk) Already seen hand therapist before or during intervention
Reasons behind why patients declined:	Unable to attend in person In prison Did not attend (DNA) Self-discharged Intoxicated COVID-related anxiety.	Patient who did not feel follow-up was required No access to or no confidence with technology DNA English translator needed ongoing anxiety with pain, wounds, or dressings

involving multiple structures made up 33% of the dataset. They required a mean of 5.1 sessions compared with 2.5 sessions for the low-risk cohort. They also required more F2F contact compared with low risk with statistical significance ($p=0.0003$).

Wound: Overall, there was no difference in the average number of follow-ups for levels of wound risk. There was, however, a statistically significant difference in the proportion of F2F contact for high-risk wounds compared with moderate- or low-risk wounds ($p < 0.05$).

Pain: Pain scores were defined using the Numeric Rating Scale (NRS).¹⁴ About 146 (52%) patients had a pain score documented at their first appointment. All patients reporting severe pain scores (7+ NRS) (6/146) required F2F follow-up. A statistically significant difference in need for the F2F follow-up was seen between mild and moderate/severe pain ($p < 0.05$).

Hand therapy input

A total of 199 patients (71%) were seen by a hand therapist after injury. A total of 46% of these (91/199) were initially seen before intervention, 7% peri-operatively, and 47% post-primary intervention. A total of 43% (121/280) required bespoke splinting, 34% required either no splints or off-the-shelf splints only, and 23% had no therapy follow-up. A total of 41% (50/121) of bespoke splinting patients were routinely offered a F2F appointment at their initial follow-up, consistent with injury management protocols.

Format of follow-up

About 953 follow-ups were performed with a mean of 3.4 per patient. A total of 46% were performed F2F and 54% remotely. A total of 88% of patients were booked an appropriate format of follow-up to optimise their outcome. Free-text comments provided qualitative data showing reasons

why patients were offered or declined F2F or TECS follow-up, as seen in [Table 2](#).

Discussion

Demographics

Age and gender did not show any statistical significance in the format of follow-up offered nor to complications or patient acceptance of the model of care.

Comorbidities

Neither patient comorbidity nor previous hand injury had a demonstrable effect on the format of follow-up. Patients with higher numbers of comorbidities were treated remotely (59% remote vs 41% F2F), in line with COVID-19 recommendations. However, the mean number of sessions and complication rate were unaffected by the format of follow-up.

Psychosocial factors

Social Factors: Although employment is recognised as a factor for patient attendance and engagement, this was not seen as significant in the format of follow-up offered. An increased injury complexity was noted in administrative workers compared with previous datasets; this may be related to an increase in DIY during lockdown¹⁵. Although administrative workers were more frequently seen remotely, because of confounding factors associated with lockdown, data did not support the use of employment type as a factor for the format of follow-up.

Limited data were available for patients with care responsibilities. No conclusion could be drawn regarding its

impact as a factor in determining format of follow-up. Further investigation into social factors, after the resumption of services post-pandemic restrictions, is needed.

Mental health: Study findings suggest that patients with pre-existing mental health were successfully treated F2F and remotely. Patients with poorly managed mental health were seen to require additional F2F care. It is reported that patients who scored higher on Anxiety and Depression (HAD) questionnaires are more likely to require opioids for pain.¹⁶ Thus F2F engagement may be important for manual interventions when mental health concerns exist.

Extent of injury

Type and number of structures: Patients with complex injuries and higher numbers of structures (>3) treated were more likely to require F2F consultation with statistical significance. Soft-tissue injuries were seen to require a higher proportion of F2F follow-up. Specialist dressing care, infection-free, and uncomplicated wound healing are paramount to optimising healing and function after trauma. Soft-tissue injury was determined to be an important factor when determining a format of follow-up.

Pain: Increased pain scores correlated with an increased number of follow-ups (mean 5.3 for moderate/severe vs 4.4 for mild). It also influenced the choice of follow-up (F2F: 46% vs 38%). Patients with severe pain scores (NRS 7+) should be considered as an indicator for the F2F follow-up.

Hand therapy factors

More than two-thirds of patients received hand therapy to optimise their recovery. High- and moderate-risk injuries required bespoke splinting both to protect injured/repared structures and to maintain position of safe immobilisation (POSI) during healing. The need for at least one F2F hand therapy review was noted for this cohort because of either bespoke splinting, wound care, or physical assessment/treatment.

Where patients did not receive the appropriate format of follow-up, 57% were due to a delayed referral to hand therapy. Our findings suggest that early input from therapy services enable improved engagement of patients and provision of aids/splints to maximise their rehabilitation, while also identifying the most appropriate format of follow-up.

Format of follow-up

A total of 85% of patients accepted their first format of follow-up; this was 93% for F2F and 81% for TECS. Reasons for refusal for remote follow-up by patients centred on practical issues such as a lack of access to technology, wi-fi capability, and anxiety about remote care.

Targeted data collection is required to further investigate clinical outcomes because of extensive recovery timeframes for injuries such as peripheral nerve injuries (PNI) and tendon repairs.

Summary

Based on a holistic review of this caseload, as well as the determination of the success of outcomes, staff appeared to be effective at offering an appropriate format of follow-up. Where concerns arose during remote consultation, formats were adapted quickly. Additional F2F treatment was offered to provide wound care, bespoke splinting, and manual therapy.

Future studies may consider the skill mix and confidence of staff in decision-making. Although patients meeting low-risk thresholds for the tool were treated safely using TECS and most follow-up decisions were correct, certain factors consistently indicated the need for F2F review. These included high-risk injuries and wounds, ≥ 3 structures repaired/treated, high pain scores and its management, the need for bespoke splinting and manual therapies, as well as mental health problems.

Refinement of the screening tool for the format of follow-up

Decision-making in a clinical environment can be complex and fast-paced. The proposed risk-stratified screening tool aims to provide a standardised approach. This helps both to justify the format of follow-up offered and support the clinician's decision-making process. The tool, as outlined in [Table 3](#), is a revision and simplification of our previous version.³ It refines the initial indicators of injury severity, mental health, and social factors to reflect factors that might limit patient outcomes, if reviewed remotely.

The structure and number of structures have remained in the tool. Study data demonstrate that high-risk injuries, such as tendons, PNI, and complex fractures, require more follow-up sessions. This is also true for the treatment of ≥ 3 structures. Moreover, statistical significance was shown for increased F2F contact in these patients. Pain is included as higher pain scores correlated with more medical/therapy input and F2F intervention. There is no substitute for F2F input for bespoke splinting and is imperative to optimise function after injury. Wound risk shows a clear trend that necessitates more F2F input in the presence of wound contamination/infection or increased complexity.

Despite low numbers of mental health patients reported, the authors feel it is important to retain mental health in the tool. Data showed that those patients with poorly controlled mental health required more F2F contact, and the literature shows that they often have more complex pain management. The authors acknowledge that HAD scores were not recorded in our data. For the purposes of providing an objective measure of potential mental health risk, it has been proposed for use in the screening tool.

Although statistical significance was shown for more F2F contact in manual workers, the decision was made to exclude employment factors. This is likely to be confounded by the fact that manual workers were more likely to have high-risk injuries and a greater number of structures requiring treatment. It was decided that their risk would likely be identified through other factors.

Table 3 Updated McMullen et al. screening tool for patients with upper-limb trauma to decide the format of follow-up.

Factor	Low RiskScore 1	Moderate RiskScore 2	High RiskScore 3 **
Structure	Simple lacerations Undisplaced/stable fractures Simple mallet injury Volar plate injury Digital nerve injury	Fractures requiring fixation Swan Neck Deformity Boutonniere Deformity Ligamentous injury	Any repaired tendon Complex fractures Peripheral nerve repair
Number of structures treated	0-1	2	≥ 3
Pain (NRS)	NRS 1-3	NRS 4-6	NRS 7-10
Splinting	No splinting/off the shelf only required	Splint adjustment required to prevent deterioration or recover range	Bespoke splint to prevent deterioration
Wound	Simple, clean	Wounds after intervention	Flaps, grafts Complex wounds Terminalised digit/limb Contaminated/infected wounds
Mental Health (HADS) *	0-7 (normal)	8-10 (borderline)	11-21 (abnormal)
Total Score =			

*Where a Hospital Anxiety and Depression (HAD) score is not possible, then clinical discretion may be used to determine level of patient anxiety and mental health risk.

**Any single high-risk score: Patients need to have at least one face-to-face follow-up.

Key:

- Scores ≤ 6: Patient can be seen remotely
- Scores ≥ 7: Clinical discretion but likely to require at least one face-to-face follow-up
- Scores ≥ 13: Face-to-face contact and likely to require regular contact.

Study limitations

This study was limited by its retrospective nature and some missing data. The unprecedented nature of the pandemic required rapid implementation, which may have affected service implementation and decision-making process across sites. Many centres did not participate in this study as neither did they have the wi-fi capacity nor the means to implement TECS. Finally, the patient follow-up period was limited to allow a distinct data capture. Therefore, complications or issues that occurred after this period may not be represented.

Conclusions

TECS is favourably reported for this patient group during a period of limited F2F contact. Data here support the assertion that a range of patient factors must be considered to create a bespoke management plan for each patient. This study highlights that, although TECS can aid clinical service provision, it should not constitute a 'blanket approach'.

Currently, there are no standardised screening tools to guide healthcare professionals in the choice of the format of follow-up. The strength of the proposed screening tool is its quantifiable nature and ease of use. It can be used prospectively to justify service provision and workforce planning. Study findings have been used to refine the tool and to reflect on the realities of delivering clinical care for this co-

hort. The findings also reinforce the need for robust technology to support this model of care.

Further prospective studies are required to validate the tool use for wider application and to explore adaptation for different population groups and skill mix of staff. Further studies may also consider any long-term outcomes of TECS use. It is important to note that, even with a risk-stratified screening tool, there is no substitute for clinical judgement and the need for continuous assessment to ensure optimal patient-centred outcomes.

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Ethical approval

Not required.

Declaration of Competing Interest

None.

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