

## **Association between the Orthopaedic Trauma Society classification of open fractures and economic costs**

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## **ABSTRACT**

**Aim:** To investigate the relationship between the Orthopaedic Trauma Society (OTS) classification of open fractures and economic costs.

**Methods:** Resource use was measured during the six months that followed open fractures of the lower limb in 748 adults recruited as part of two large clinical trials within the UK Major Trauma Research Network. Resource inputs were valued using unit costs drawn from primary and secondary sources. Economic costs (UK£, 2017-18 prices), estimated from two perspectives: (i) a National Health Service (NHS) and Personal Social Services (PSS) perspective, and (ii) a societal perspective were related to the degree of complexity of the open fracture based on the OTS classification.

**Results:** Adjusted mean total NHS and PSS costs were £13,785 following treatment of complex fractures and £3,550 following treatment of simple fractures, where the open fracture wound is closed at the end of the first wound debridement, generating a mean difference of £10,235 (95% CI £8,074 to £12,396).

**Conclusion:** Following previous work correlating clinical outcomes with the OTS classification of open fractures, this study suggests that the new OTS classification also correlates with economic costs estimated from alternative study perspectives.

## INTRODUCTION

The Orthopaedic Trauma Society (OTS) classification is based upon an objective assessment of open fracture wound at the end of the first wound excision (debridement)<sup>1</sup>. It classifies open fractures as either 'simple' (i.e. primary closure of the open fracture wound that can be achieved following wound excision) or 'complex' (i.e. reconstructive procedure is needed to close the wound). Complex fractures can be further classified into three groups to reflect the extent of the reconstructive intervention. 'Complex A' are cases where the wound can be closed primarily but bone deformation or acute bone shortening is required to facilitate closure; 'complex B' are those where the wound closure requires a soft-tissue reconstructive procedure; and 'complex C' are those where the wound closure requires repair/reconstruction of an associated vascular injury.

In a previous study, we reported that the OTS classification system correlates well with patient-reported disability and health-related quality of life, using Disability Rating Index (DRI) scores and EuroQol five-dimension questionnaire (EQ-5D) utility values during the 12 months after the injury. We also noted that the OTS classification did not correlate with deep surgical site infection at 30 days<sup>1</sup>.

The United Kingdom (UK) has one of the highest annual healthcare expenditures in the world<sup>2</sup>. In 2020, spending on health care in the UK totalled £269.5 billion or 12.8% of the gross domestic product (GDP) compared with £158.0 billion or 9.8% in 2010<sup>2</sup>. Furthermore, in 2010, immediate treatment of major trauma was estimated to cost the National Health Service (NHS) between £0.3 and £0.4 billion (or between 0.19% and 0.25% of the GDP) a year<sup>2,3</sup>. With healthcare systems under rising economic pressure worldwide, there is an increasing interest in the management of finite resources in this clinical area.

In this study, we describe the correlation between the OTS classification of open fractures and economic costs at 3- and 6-months post-injury from a NHS and Personal Social Services (PSS) perspective, as well as a broader societal perspective.

## METHODS

### Study population and data sources

A total of 748 participants with open fractures of the lower limb were included from two large trials. The Wound Healing in Surgical Trauma (WHIST) trial recruited adult patients with open fractures closed primarily after the first surgical wound excision, whilst the Wound Management of Open Lower Limb Fractures (WOLLF) trial recruited adult patients with open fractures that could not be closed primarily. Full details of the trials and their sampling procedures, methodology, clinical outcome measures, and response rates are reported elsewhere<sup>4-7</sup>. Both WHIST (16/WM/0006) and WOLLF (10/57/20) have been approved by the UK National Research Ethics Committee. Baseline characteristics of the participants have been reported elsewhere<sup>1</sup> but to summarise, 288 (38.5%) had a simple open fracture, and 460 (61.5%) had a complex fracture as defined by the OTS classification system. Among those with complex fractures, 79 (10.6%) had a complex A fracture, 336 (44.9%) had complex B fracture, and 45 (6.0%) had a complex C fracture. The majority of the participants were male (simple 191 (66.3%), complex 342 (74.3%)) and the participants had a median age of 42 years (27 to 56 years) and 43 years (28 to 59 years) for simple and complex fractures, respectively<sup>1</sup>.

Patient-reported health and social service resources consumed due to the open fracture were described at baseline, 3- and 6-months post-injury with a recall period of three months. This included

the initial care - costs of wound and fracture management and inpatient care (i.e. hospitalisation, further treatment procedures change of dressing etc); subsequent inpatient care after discharge; hospital outpatient care (i.e. orthopaedics, pathology, radiology, physiotherapy, and emergency department); community health care (i.e. general practitioner, practice nurse, district nurse, community physiotherapy, occupational therapist, and calls to NHS 111 or ambulance); personal social services (meal-on-wheels, laundry, social worker and care worker); medications; aids and adaptations; additional care (or direct non-medical costs) such as travel, child care and help with housework as well as time off work due to injury. Unit cost for the resource inputs within the respective trials have been reported elsewhere.<sup>8,9</sup> Economic costs from WOLFF (in 2014/15 prices) were inflated to 2017/18 prices to match those reported in WHiST.

In order to reduce the amount of missing data, we have assumed that if one category of resource use within a patient questionnaire was completed (e.g. hospital outpatient care) and if the others were not completed, values for resource use and therefore economic costs for incomplete resource categories were zero.

### **Statistical analysis**

Using the available-case data set, consisting of all observed data, a two-part model<sup>10</sup> was used to generate unadjusted and adjusted mean costs over the six month follow-up period associated with alternative degrees of complexity of fracture. The two-part model accounted for the skewed distribution of economic costs and had two stages: (i) a logistic regression, in which the dependent variable (total economic costs) indicated presence of zeros costs (yes, no); followed by (ii) a generalised linear model (GLM) with a gamma distribution and log link function for economic costs relating to participants with positive values. In keeping with the analysis plan for the patient-reported outcomes<sup>1</sup>, the models were adjusted for participant age at baseline, participant sex, randomized treatment, and for baseline (pre-injury) values of DRI scores and EQ-5D utilities. A sensitivity analysis replicated the analysis using total economic cost estimated from a societal perspective as the dependent variable; the societal perspective includes economic values placed on time off work, as well as NHS services and state-funded social services, and facilitates policies aimed at maximising the welfare gains or minimising the losses to society more broadly<sup>11</sup>.

## **RESULTS**

The unadjusted and adjusted mean total costs associated with complex fractures were significantly higher than those for simple fractures from both the NHS and PSS perspective and the separate societal perspective over the six months post-injury (Table 1). Figures 1 and 2 display disparities in economic costs both between simple and complex fracture types and over follow-up periods. The mean adjusted cost associated with fracture decreases over time, regardless of fracture type, with the first hospital admission being the main cost driver. The adjusted mean total costs over the six months post-injury period associated with simple fracture was significantly lower than that of each category of complex fracture (Table 2) from both a NHS and PSS perspective and a societal perspective. However, there were no statistically significant differences in adjusted mean total cost between the sub-categories of complex fractures from both a NHS and PSS perspective and a societal perspective.

## **DISCUSSION**

This study of the OTS classification of open fractures shows that the adjusted mean total cost of a simple fracture was statistically significantly lower than that of a complex fracture from a NHS and PSS perspective as well as a societal perspective in the UK.

The economic costs described in this study are similar to those reported in previous assessments of resource use following an open fracture of the lower limb. Tissingh et al.<sup>12</sup> reported an in-hospital cost of managing open lower limb fractures in a Major Trauma Centre (MTC) in the UK. That study used patient-level data to estimate the cost of these injuries in a cohort of patients of all ages (mean age 40 years), showing a median cost of inpatient treatment of £19,189 per fracture in 2014/15 prices. More recently, Pley et al.<sup>13</sup> reported the financial implications of the inpatient management of open lower limb fractures in older adults (65 years and over). They found the median cost of an open femur fracture was £23,949 (mean £23,119), the median cost of an open tibia fracture was £24,549 (mean £28,990) and the median cost of an open ankle fracture was £15,362 (mean £14,862) in 2019/2020 prices. Since the methods employed in both studies only include a limited number of cost components – notably excluding non-health care resource use, as well as healthcare resource use after the index hospital stay - the results are likely to underestimate the total economic cost associated with open fractures.

In the UK, the standards of treatment for open fractures have been defined jointly by the British Orthopaedic Association (BOA) and the British Association for Plastic, Reconstructive and Aesthetic Surgery (BAPRAS). Across the Major Trauma Network, patients with serious traumatic injuries, including those with open fractures, are taken directly to a designated Major Trauma Centre. These centres facilitate joint care of patients with open fractures with orthopaedic trauma surgeons and plastic surgeons, creating centres with ‘orthoplastic’ care<sup>14,15</sup>. Coordinated efforts and models of shared decision-making have increased confidence in early wound excision and definitive wound closure, even in association with severe contamination, which has ultimately led to lower rates of deep surgical site infection<sup>4,6,14</sup>. Reducing the incidence of complications is important for patients and for the management of healthcare resources. For example, patients with postoperative infections following an open fracture require significantly more healthcare resources than those without infection, thus driving healthcare and societal costs<sup>16</sup>. Olesen et al.<sup>17</sup> have recently shown that the mean cost of open tibial fractures without infection was €49,817 (in 2014 prices), but this increased by 63% (€81,155) when an infection occurred.

Estimating the resource implications associated with major clinical events informs the budgetary and service planning of centres providing orthoplastic services for patients with open fractures. Theoretically, resource use and economic cost could be associated with the severity of the open fracture and the subsequent risk of complications. This study confirms this assumption<sup>18</sup>, demonstrating that the OTS classification, which separates simple open fractures, where the wound can be closed primarily at the end of the first surgical debridement, from complex open fractures, where a reconstructive procedure is required, correlates with overall resource use and hence economic cost. The initial hospital admission, including wound and fracture management and inpatient care, was identified as the main cost driver. The elevated mean cost of initial care for patients with a complex fracture is explained by the fact that these patients require additional reconstructive surgery, but the data also indicates that patients with complex open fractures have higher ongoing costs during the six months that follow the injury, compared with patients who have simple open fractures<sup>9</sup>.

A key strength of this study is that it estimated economic costs from both a NHS and PSS perspective, and a broader societal perspective. Resource use data were collected using patient questionnaires, which allowed for the inclusion of direct non-medical costs such as aids and adaptations at home, travel, childcare and help with housework required due to the open fracture, and indirect cost (i.e. valuation of time off work that could not otherwise be collected using routine datasets or registry data). The key limitation of the study is its constrained time horizon. Although resources related to the management of open fractures are usually consumed within the first few months after the injury, external observational studies suggest that patients with these life-changing injuries do have ongoing care needs and resource requirements up to at least five years<sup>19</sup>. Another limitation is the assumptions made to reduce the volume of missing data in this analysis. Nevertheless, this affected only 72/748 (9.6%) participants' observations and therefore likely had limited impact on the study conclusions.

In summary, this study shows that the simple versus complex classification of open fractures, as described in the OTS classification, correlates with economic costs estimated from alternative study perspectives. The OTS classification of open fractures could act as an aid for allocating appropriate resources to centres treating these injuries according to the severity of the open fracture.

### **TAKE-HOME MESSAGE**

- The adjusted mean total cost of simple fracture is statistically significantly lower than that for complex fractures from a NHS and personal social services perspective as well as a societal perspective.
- The initial hospital admission represents the main driver of resource use and hence economic cost, but patients with open fractures also require considerable further resources during the six months following their injury.

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### **CONFLICT OF INTEREST**

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## AUTHOR CONTRIBUTIONS

ME Png: Investigation, Formal analysis, Methodology, Writing - Original Draft, Writing - Review & Editing.

S Petrou: Supervision, Writing - Review & Editing.

J Bourget-Murray: Writing - Original Draft, Writing - Review & Editing.

R Knight: Data curation, Investigation, Writing - Review & Editing.

A Trompeter: Conceptualisation, Writing - Review & Editing.

ML Costa: Conceptualisation, Investigation, Resources, Writing - Original Draft, Writing - Review & Editing.

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## FIGURES

Figure 1. Breakdown of adjusted mean cost of resource use (£) at each time point: Simple versus Complex (£, 2017/18 prices)

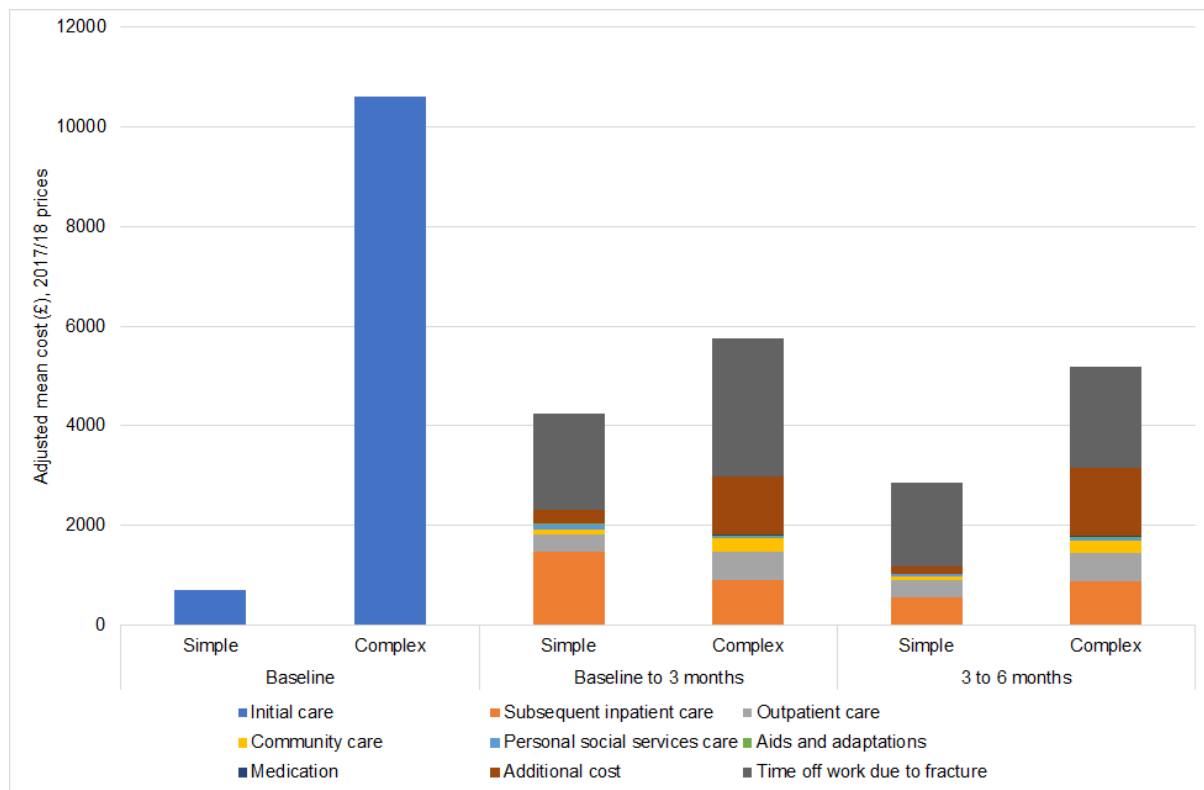
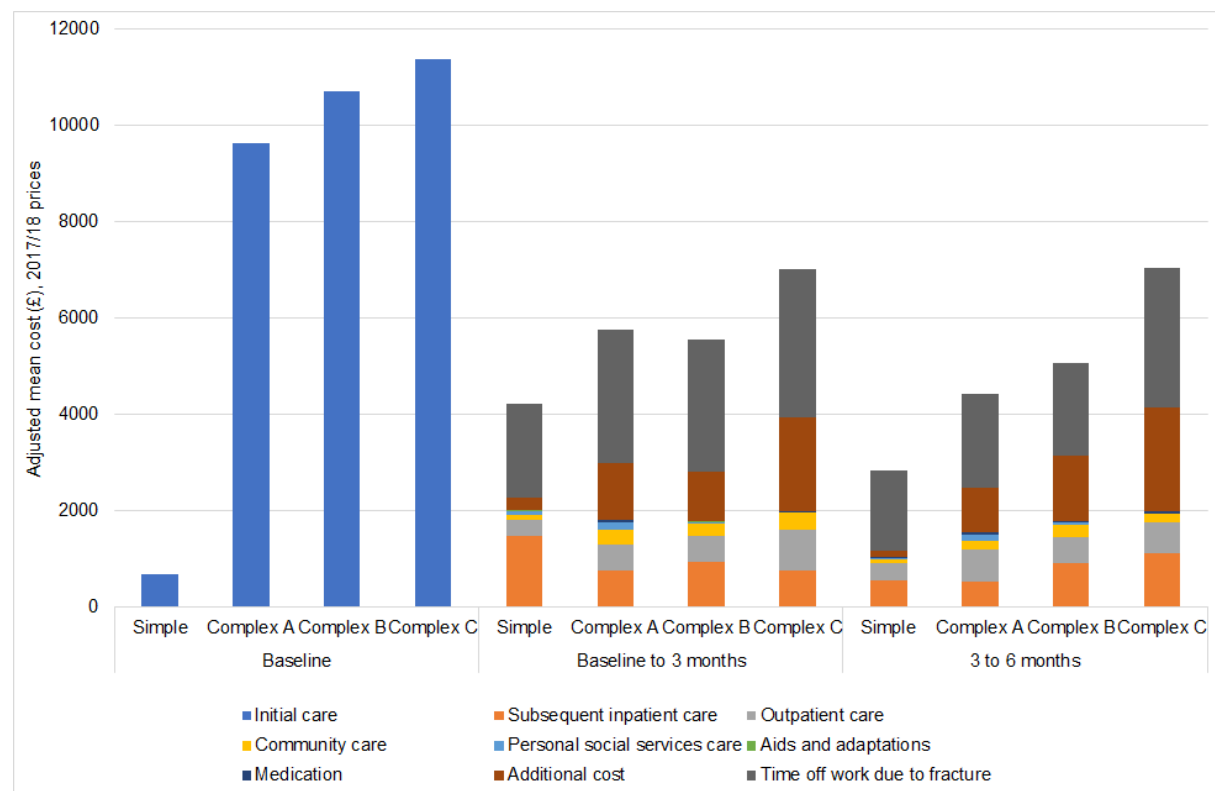


Figure 2. Breakdown of adjusted mean cost of resource use (£) at each time point: Simple versus Complex A/B/C (£, 2017/18 prices)



## TABLES

Table 1. Unadjusted and adjusted mean total cost (£) for simple versus complex fractures over six months post-injury, in 2017/18 prices (available-case)

	Unadjusted mean total cost				Adjusted mean total cost			
	Simple (n=166)	Complex (n=277)	Difference	(95%CI)	Simple (n=161)	Complex (n=277)	Difference	(95%CI)
NHS and PSS perspective	3,666	13,726	10,060	(7,843 to 12,277)	3,550	13,785	10,235	(8,074 to 12,396)
Societal perspective	7,404	21,187	13,784	(11,111 to 16,456)	7,425	20,916	13,491	(10,846 to 16,136)

NHS: National Health Service, PSS: Personal Social Services

Table 2. Difference (95%CI) in adjusted mean total cost (£) between each fracture type over six months post-injury, in 2017/18 prices (available-case)

	Simple vs. Complex A	Simple vs. Complex B	Simple vs. Complex C	Complex A vs. Complex B	Complex A vs. Complex C	Complex B vs. Complex C
NHS and PSS perspective	9,885 (4,952 to 14,818)	10,179 (7,737 to 12,620)	11,268 (4,305 to 18,230)	804 (-1,196 to 2,804)	1,023 (-2,318 to 4,364)	394 (-2,217 to 3,004)
Societal perspective	12,689 (6,875 to 18,503)	13,259 (10,313 to 16,206)	16,437 (7,770 to 25,105)	1,154 (-1,894 to 4,202)	3,843 (-2,930 to 10,616)	2,973 (-1,717 to 7,663)

NHS: National Health Service, PSS: Personal Social Services