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Undertreatment of acute pain (oligoanalgesia) and medical practice variation in prehospital analgesia of adult trauma patients: a 10 yr retrospective study

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Editor's key points

- There is evidence of undertreatment of pain in trauma patients at the prehospital stage.
- This retrospective review of patient records did find some undertreatment of pain.
- A number of factors increase the likelihood of oligoanalgesia, including being treated by a female physician, having severe pain before starting treatment, and being treated by a relatively junior member of the team.
- Further research is needed to clarify causal links and understand further the factors underlying oligoanalgesia.

Background. Prehospital oligoanalgesia is prevalent among trauma victims, even when the emergency medical services team includes a physician. We investigated if not only patients' characteristics but physicians' practice variations contributed to prehospital oligoanalgesia.

Methods. Patient records of conscious adult trauma victims transported by our air rescue helicopter service over 10 yr were reviewed retrospectively. Oligoanalgesia was defined as a numeric rating scale (NRS) >3 at hospital admission. Multilevel logistic regression analysis was used to predict oligoanalgesia, accounting first for patient case-mix, and then physician-level clustering. The intraclass correlation was expressed as the median odds ratio (MOR).

Results. A total of 1202 patients and 77 physicians were included in the study. NRS at the scene was 6.9 (1.9). The prevalence of oligoanalgesia was 43%. Physicians had a median of 5.7 yr (inter-quartile range: 4.2–7.5) of post-graduate training and 27% were female. In our multilevel analysis, significant predictors of oligoanalgesia were: no analgesia [odds ratio (OR) 8.8], National Advisory Committee for Aeronautics V on site (OR 4.4), NRS on site (OR 1.5 per additional NRS unit >4), female physician (OR 2.0), and years of post-graduate experience [>4.0 to ≤5.0 (OR 1.3), >3.0 to ≤4.0 (OR 1.6), >2.0 to ≤3.0 (OR 2.6), and ≤2.0 yr (OR 16.7)]. The MOR was 2.6, and was statistically significant.

Conclusions. Physicians' practice variations contributed to oligoanalgesia, a factor often overlooked in analyses of prehospital pain management. Further exploration of the sources of these variations may provide innovative targets for quality improvement programmes to achieve consistent pain relief for trauma victims.

Keywords: clinical practice variation; emergency medical services; physician's practice patterns; prehospital emergency care; wounds and injuries

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Acute pain is common in prehospital medicine and is experienced by 35–70% of trauma patients.[1 2] Efficient analgesia reduces both physiological and psychological stress, and in the prehospital setting, it also facilitates extrication from wreckage and therapeutic manoeuvres.[2] However, the emergency medicine literature reports that acute pain is undertreated, a phenomenon defined as oligoanalgesia.[3] The available emergency medicine literature to date focuses on patients' characteristics (i.e. patient gender[4] or age)[5] as determinants of oligoanalgesia. Prehospital oligoanalgesia results from either a complete lack of analgesia (unrelieved pain)[4 6–8] or an insufficient dose of analgesics (unachieved analgesia), both of which are the results of a medical decision.[9] Physicians have recently been logically included as additional determinants of this phenomenon. Significant variation in analgesic decision-making among emergency physicians has been documented using written vignettes,[10 11] and also from studying physicians' actions in the emergency department (ED),[12] but never in the prehospital setting.

The primary goal of this 10 yr retrospective study was to assess how oligoanalgesia was associated with physicians' practice variation among non-intubated adult trauma patients transported by our physician-staffed air-medical transport system to our ED, taking into account both patients' and physicians' characteristics. A secondary goal was to assess if oligoanalgesia was related to undelivered analgesia, or delivered but unachieved analgesia.

Methods

Study design

This was a single centre, retrospective chart review of trauma patients transported from the accident site to our hospital by helicopter between January 1, 1997, and December 31, 2006. This retrospective study was approved by the Ethics Committee of our institution.

Setting

Our University Hospital is a level 1 trauma centre, and the physician-staffed air rescue helicopter is dispatched to the scene based on alarm keywords and location of the emergency.[13] The physician is either a member of the ED staff or is a resident. Residents rotate to the ED for 6 or 12 months from the internal medicine or anaesthesiology residency programmes of our institution, after having completed a minimum of 1 yr of residency in the anaesthesiology department. According to our pain management protocol, acute pain was assessed using the numeric rating scale (NRS) and documented both on site and upon hospital arrival. Pain was treated with i.v. fentanyl 0.5–2 $\mu g\ kg^{-1}$ in small incremental doses, targeting an NRS $\leq$3. There was no explicit limit to dose intervals or maximum cumulative dose, and all doses were based on the degree of pain relief needed. Injections of other medications such as benzodiazepines or ketamine were left to the physicians' discretion. After each transport mission, physicians filled out a standardized report recording a short description of the case, the patient's characteristic data, vital signs, physical examination, and initial prehospital diagnoses. An attending physician verified that all report items were completed. Thereafter, a data manager inputted all data into a Filemaker® database (Filemaker 5, Santa Clara, CA, USA).

Selection of participants

All consecutive non-intubated adult trauma patients were screened for inclusion in the study. Inclusion criteria were: age 16 yr or older, a Glasgow coma scale (GCS) $\geq$13 both on site and upon hospital arrival, and an NRS $>$3 at the scene. The 11-point NRS is anchored with 0 as no pain and 10 as maximal imaginable pain. Patients were excluded from the analysis if NRS was not recorded at the scene or upon arrival at hospital or if GCS decreased below 13 at hospital. Oligoanalgesia was defined as an NRS $>$3 upon arrival in our ED;[14] patients were included if oligoanalgesia was due to a lack of analgesics (unrelieved pain) or due to an insufficient dose of analgesics (unachieved analgesia). All patients were assessed by the prehospital physician according to the Munich modification of the National Advisory Committee for Aeronautics (NACA) score,[15] and by the injury severity score (ISS).[16] Physicians' characteristics were retrieved from our administrative database.

Statistical analysis

Subjects were dichotomized into groups according to oligoanalgesia on admission. Summary statistics were presented as proportions (%), means and standard deviations (SD), or when specified, as medians and inter-quartile range (IQR) for skewed data. Bivariate associations between the outcome variables and the independent variables were assessed using the χ^2 test for discrete predictors. The most appropriate transformation for continuous predictors was assessed using simple logistic regression along with fractional polynomial dose–response modelling.

Our data have a hierarchical structure with regard to analgesia; the individual interventions are nested within a cluster of physician interventions. Therefore, multilevel logistic regression analysis was used. The impact of physician unmeasured characteristics (contextual factors) was quantified using the median odds ratio (MOR), whereas the interval odds ratio (IOR) was used to assess the importance of physician measured characteristics. As neither the variance nor the distribution of the MOR is known, nested studentized Bootstrap (Bootstrap-*t*) confidence intervals were calculated. A detailed description of the statistical analyses used can be found in Appendix 1.

Estimations were made using maximum likelihood. Goodness-of-fit analyses were performed using the Hosmer–Lemeshow test, and the area under the receiver operating characteristic (ROC) curve. All analyses were performed using STATA 11.2 (Stata Corporation, College Station, TX, USA).

Results

Study population

A total of 4904 transport missions were reviewed, and 1202 patients met the inclusion criteria (Fig. 1). The mean age was 39 (17) yr and the majority was male (Table 1). On average, vital signs were within normal limits on site (data not shown), but tachypnoea was present in 16%, and hypoxaemia in 2.1% of victims. The most frequently injured body areas were the limbs, and 50% of patients had multiple injuries. The majority of patients had an NACA score $>$II. The mean ISS was 9.8 (8.4), and nearly one-quarter of all patients had an ISS $>$15.

Overall, 14 patients (1.2%) had a GCS $<$13 on arrival (Fig. 1); of whom, 10 (71%) were oversedated; all of them had received a combination of at least two central nervous system depressants (Appendix 2).

Pain at the scene was moderate to severe, and was significantly higher in men. Fentanyl was administered to the majority of patients. Ketamine was the only analgesic used in 2.1% of patients. Pain alleviation between the accident site and hospital was 3.5 (2.3) units ($P<0.001$); both genders experienced the same pain reduction of 3.4 units ($P=0.94$). The absolute NRS reduction was greater when initial NRS was higher (Table 2).

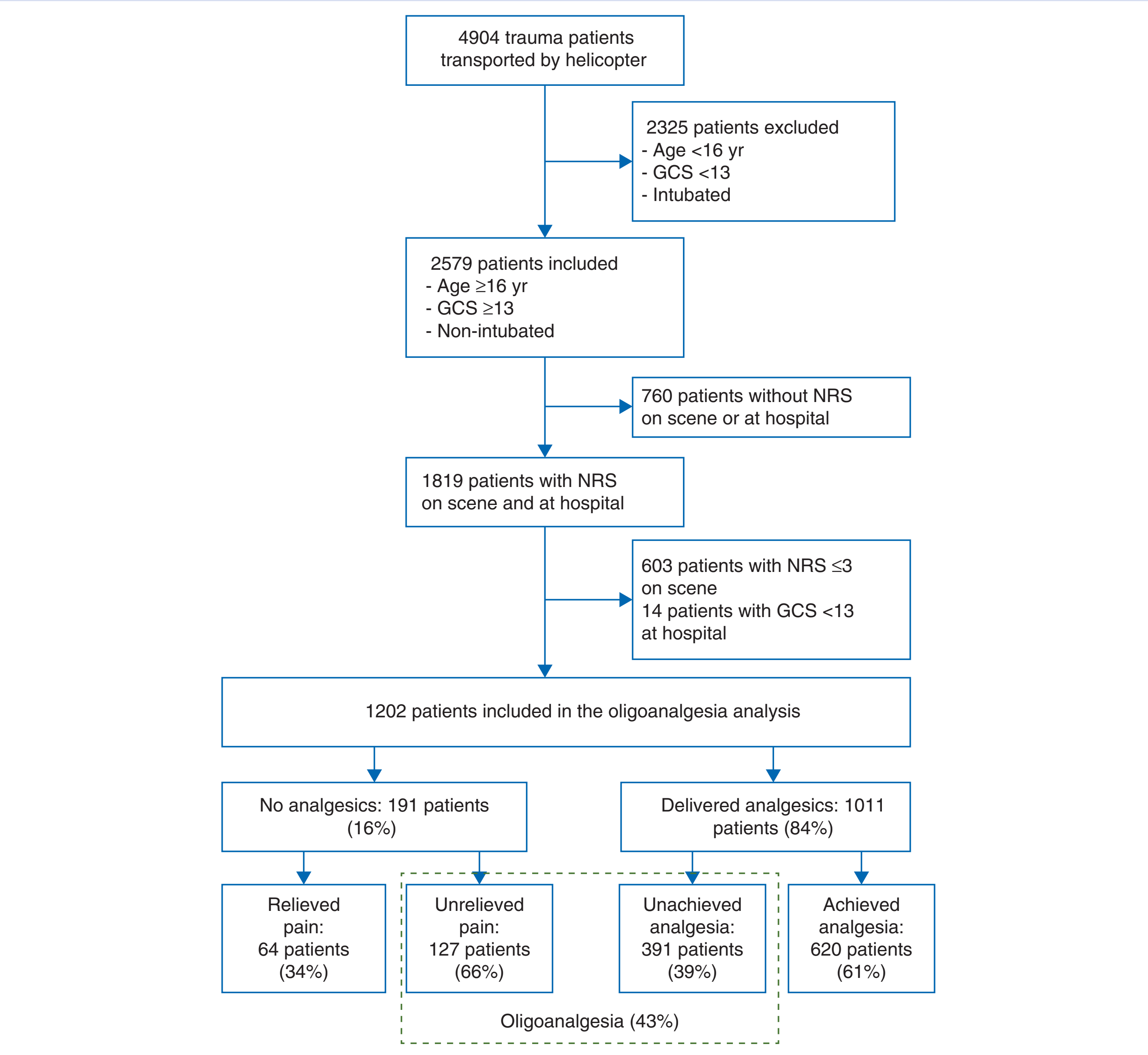

Fig 1 Flow chart of study patients. GCS, Glasgow coma scale; NRS, numeric rating scale.

Oligoanalgesia

Oligoanalgesia affected 43% of the study patients (Fig. 1). Oligoanalgesia patients were more likely to be male, had higher NACA scores, and a larger proportion had an ISS >15 and a higher NRS at the scene (Table 1). The percentage of oligoanalgesia became larger with greater pain severity at the scene (Fig. 2). Oligoanalgesia was due to unachieved analgesia or unrelieved pain in 75% and 25% of cases, respectively ($P<0.001$); however, the proportion of unrelieved pain was larger than unachieved analgesia when the NRS score at the scene was <6 (Fig. 2).

Unrelieved pain and unachieved analgesia

The proportion of oligoanalgesia was higher when analgesics were not delivered: 66% *vs* 39% for patients who received analgesia ($P<0.001$; Fig. 1).

Patients with unachieved analgesia differed from those who reached a pain severity <3 upon arrival (Table 2): they were more often male, their respiratory rate on site was higher ($P<0.001$), they had higher NACA and ISS scores, and a higher NRS on site. The proportion of unachieved analgesia grew larger with increasing NRS at the scene ($P<0.001$; Fig. 2). Male patients received higher non-weight-adjusted doses of fentanyl than did females but experienced the

Table 1 Characteristics of the study population by oligoanalgesia. IQR, inter-quartile range; NACA, National Advisory Committee for Aeronautics score; ISS, injury severity score; NRS, numeric rating scale; n.a., not applicable; *<0.05 for male *vs* female in the same column

	Study population (*n*=1202)	Analgesia (*n*=684)	Oligoanalgesia (*n*=518)	*P*-value
Patients' characteristics				
Age (yr) (range)	39 (16–93)	39 (16–93)	38 (16–90)	0.34
Male (%)	71	69	75	0.03
Respiratory rate (bpm) (SD)	20 (6)	20 (6)	21 (6)	<0.001
Median oxygen saturation on site (%) (IQR)	99 (96; 100)	99 (97; 100)	99 (97; 100)	0.03
NACA score (%)				
II	5.8	5.9	5.7	0.01
III	46	49	43	
IV	42	41	43	
V	5.8	4.1	8.3	
Injury location				
Abdomen (%)	25	23	27	0.20
Surface/external (%)	18	19	17	0.44
Face (%)	11	12	11	0.72
Limbs (%)	66	68	64	0.09
Thorax (%)	35	35	34	0.76
Head (%)	31	33	29	0.18
ISS >15 (%)	23	21	26	0.04
NRS at the scene (units) (SD)	6.9 (1.9)	6.5 (1.8)	7.3 (1.9)	<0.0001
Male	6.9 (1.9)*	6.6 (1.8)	7.4 (1.9)	<0.0001
Female	6.7 (1.9)	6.4 (1.8)	7.0 (1.9)	0.004
NRS at hospital (units) (SD)	3.4 (1.9)	2.1 (1.0)	5.1 (1.5)	n.a.
Male	3.5 (1.9)*	2.1 (0.9)	5.1 (1.4)	n.a.
Female	3.2 (2.0)	2.0 (1.0)	5.3 (1.6)	n.a.
Absolute NRS reduction between site and hospital (units) (SD); according to NRS at the scene				
4–6	2.2 (1.6)	3.1 (1.2)	0.6 (0.8)	<0.0001
7–8	4.0 (1.9)	5.4 (1.0)	2.5 (1.4)	<0.0001
9–10	5.3 (2.1)	7.6 (1.0)	3.8 (2.0)	<0.0001
Analgesics (%)	84	91	75	<0.0001
Fentanyl	82	86	70	<0.0001
Ketamine	5	6.3	3.3	0.02
Physicians' characteristics				
Female (%)	21	16	30	<0.001
Anaesthesiology track (%)	83	83	82	0.49
Residents (%)	88	87	90	0.13
Median post-graduate training (yr) (IQR)	5.7 (4.2; 7.5)	5.7 (4.2; 7.6)	5.5 (4.2; 7.3)	0.12

same reduction in pain severity [3.8 (2.0) *vs* 4.0 (2.2), *P*=0.1]. Although doses of fentanyl increased significantly with greater pain severity, the doses were not different between patients with achieved or unachieved analgesia (Table 2).

Physicians

A total of 77 physicians were included in the study; 73% were male, and 83% were residents; of which, 91% were anaesthesiologists. On average, physicians had 5.7 yr of post-graduate training (Table 1). The median number of missions per physician was 13 (IQR 8–20), with a range of 1–54 missions (Fig. 2). The median number of missions was not significantly different between female (12, IQR 8–14) and male physicians (16, IQR 8–22) (*P*=0.14). Physicians' average percentage of oligoanalgesia, unrelieved pain, and unachieved analgesia in their patients were 49%, 19%, and 47%, respectively, but interindividual percentages varied significantly (all *P*<0.001, Fig. 3A).

Oligoanalgesia and unachieved analgesia were nearly twice as common when the physician was female (*P*<0.001). Although there were no significant differences in physicians' characteristics regarding unrelieved pain, differences existed regarding unachieved analgesia (Table 2). Female physicians administered significantly lower fentanyl doses than did male physicians, and their patients experienced a smaller reduction in NRS: 3.5 (2.1) *vs* 4.0 (2.0) (*P*<0.001).

Table 2 Delivered analgesia: characteristics of patients with delivered analgesics by achieved and unachieved analgesia. NACA, National Advisory Committee for Aeronautics numeric rating score; ISS, injury severity score; NRS, numeric rating scale. *<0.001 for doses across pain severity in the same group;[†]<0.01 for doses between physician gender in the same group

	Delivered analgesics (n=1011)	Achieved analgesia (n=620)	Unachieved analgesia (n=391)	P-value
Patients' characteristics				
Age (yr) (range)	39 (16–93)	40 (16–93)	38 (16–90)	0.47
Male (%)	73	70	79	0.001
Respiratory rate (bpm) (SD)	21 (6)	20 (6)	22 (6)	<0.001
NACA score (%)				
II	3.6	5.0	1.3	<0.001
III	45	48	40	
IV	45	42	49	
V	6.3	4.4	9.5	
ISS >15 (%)	26	22	31	0.003
NRS at the scene (units) (SD)	7.1 (1.8)	6.7 (1.8)	7.9 (1.7)	<0.001
NRS at hospital (units) (SD)	3.3 (1.9)	2.1 (0.9)	5.2 (1.5)	<0.001
Physicians' characteristics				
Female (%)	22	16	30	<0.001
Anaesthesiology track (%)	83	84	82	0.39
Residents (%)	89	87	90	0.19
Median post-graduate training (years) (IQR)	5.7 (4.2; 7.5)	5.7 (4.2; 7.6)	5.6 (4.2; 7.3)	0.14
Medications				
Fentanyl (%)	94	95	93	0.13
Mean dose (μg) (SD)	157 (108)	153 (109)	162 (105)	0.22
By patient gender				
Female	136 (100)	132 (103)	143 (95)	0.43
Male	164 (109)*	162 (111)	167 (108)	0.58
By NRS on site:				
NRS 4–6	116 (88)	119 (93)	107 (68)	0.27
NRS 7–8	167 (101)	175 (106)	159 (93)	0.12
NRS 9–10	213 (125)*	226 (126)*	205 (125)*	0.25
By physician gender				
Female	135 (86)	123 (86)	147 (86)	0.04
Male	162 (112)[†]	159 (112)[†]	169 (112)	0.26
Ketamine (%)	5.9	6.9	4.4	0.09

In our multivariable analysis for oligoanalgesia, patient male gender, unrelieved pain, higher NACA scores, and treatment by a female physician or a less experienced physician of either sex increased the odds of oligoanalgesia (Table 3). The physician intraclass correlation (ICC), expressed here as the MOR, was 2.6, indicative of a significant interphysician variation associated with oligoanalgesia (Fig. 3B). The IOR for post-graduate experience was large, indicating that the unexplained residual variation (unexplained context heterogeneity) between physicians was large, even after adjusting for available physicians' characteristics. Only the IOR for a post-graduate experience ≤2 yr did not contain the value of 1, indicating that a lack of clinical experience had a large effect compared with the residual variation between physicians. Interactions between the physician's and patient's gender were not statistically significant (data not shown). The area of the ROC curve of our model was 0.84, and the P-value of the Hosmer–Lemeshow goodness-of-fit analysis was not statistically significant (P=0.58), indicating that our model fit the data.

Discussion

In our physician-staffed medical air transport system, moderate-to-severe acute pain affected 67% of trauma patients, confirming the burden of acute pain in the prehospital setting for trauma patients.[1 4] Overall, physicians administered analgesics to 84% of patients, and pain decreased 3.5 units on average during transportation, a clinically significant reduction, with rare adverse events.[17] However, oligoanalgesia still affected 43% of all patients, a consequence of two factors: unrelieved pain, in particular at pain severities

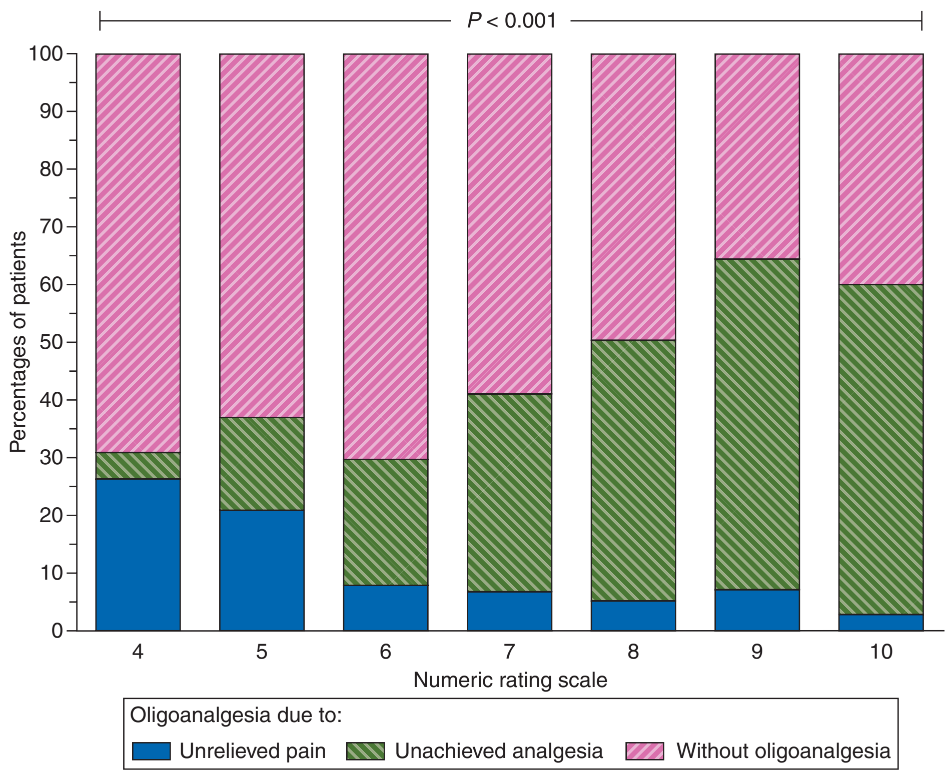

Fig 2 Proportion of patients with and without oligoanalgesia by pain severity on site.

<6, and insufficient analgesia at pain severities ≥6 on the NRS scale.

Our study demonstrated that pain management and the probability of oligoanalgesia varied significantly between physicians, which constituted a source of unintended variation in the ability of our prehospital system to treat pain adequately. Our prehospital data confirm management practice variations reported previously.[10–12] A shorter duration of post-graduate training and female gender were two characteristics of the physician that increased the probability of oligoanalgesia. Less experienced physicians may spend more of the prehospital mission time taking care of tasks other than pain management, be less familiar with the hospital's pain management protocol or overestimate the risk–benefit ratio of fentanyl in the prehospital setting.[18] Female physicians administered lower doses of fentanyl and obtained smaller pain reductions which doubled the likelihood of unachieved analgesia. Some studies in specialities outside emergency medicine suggest that female physicians may treat their patients less aggressively than do male doctors.[19 20] However, our wide IORs associated with physician's gender or experience show that these are weak predictors of oligoanalgesia, compared with the unexplained residual probability of oligoanalgesia between physicians. A limited role for these two global factors is supported by recent research from the social cognition domain that shows the physician's judgement required to treat pain is influenced by numerous external and personal factors, among which affect (or empathy) and the uncertainty of the diagnosis play a large role.[21] As pain management was so variable, our study indicates that this variability constitutes a valuable target for quality improvement intervention;[22] rapid feedback based on individual performance might be an effective educational tool to reduce practice variations and improve pain management.[23]

The dose of administered fentanyl corresponded to ∼1–2 $\mu g\ kg^{-1}$. This dose was lower than the theoretical maximal dose in some protocols,[24] but similar to[9 24 25] or larger than doses actually provided in other studies.[26 27] Increasing pain severities on site and severe injuries were patients' factors associated with oligoanalgesia. More severe pain on site was associated with a lower proportion of unrelieved pain but a larger proportion of unachieved analgesia despite higher doses of fentanyl. Although physicians adjusted the doses of fentanyl to the patient's initial NRS, they did not further increase the doses when NRS remained >3. Several explanations are possible. Side-effects may have precluded the use or limited the doses of additional fentanyl in unstable patients. Alternatively, physicians may have voluntarily limited the amount of fentanyl administered for fear of side-effects, or underestimated the doses of opioids required to treat severe pain.[28] Unachieved analgesia was

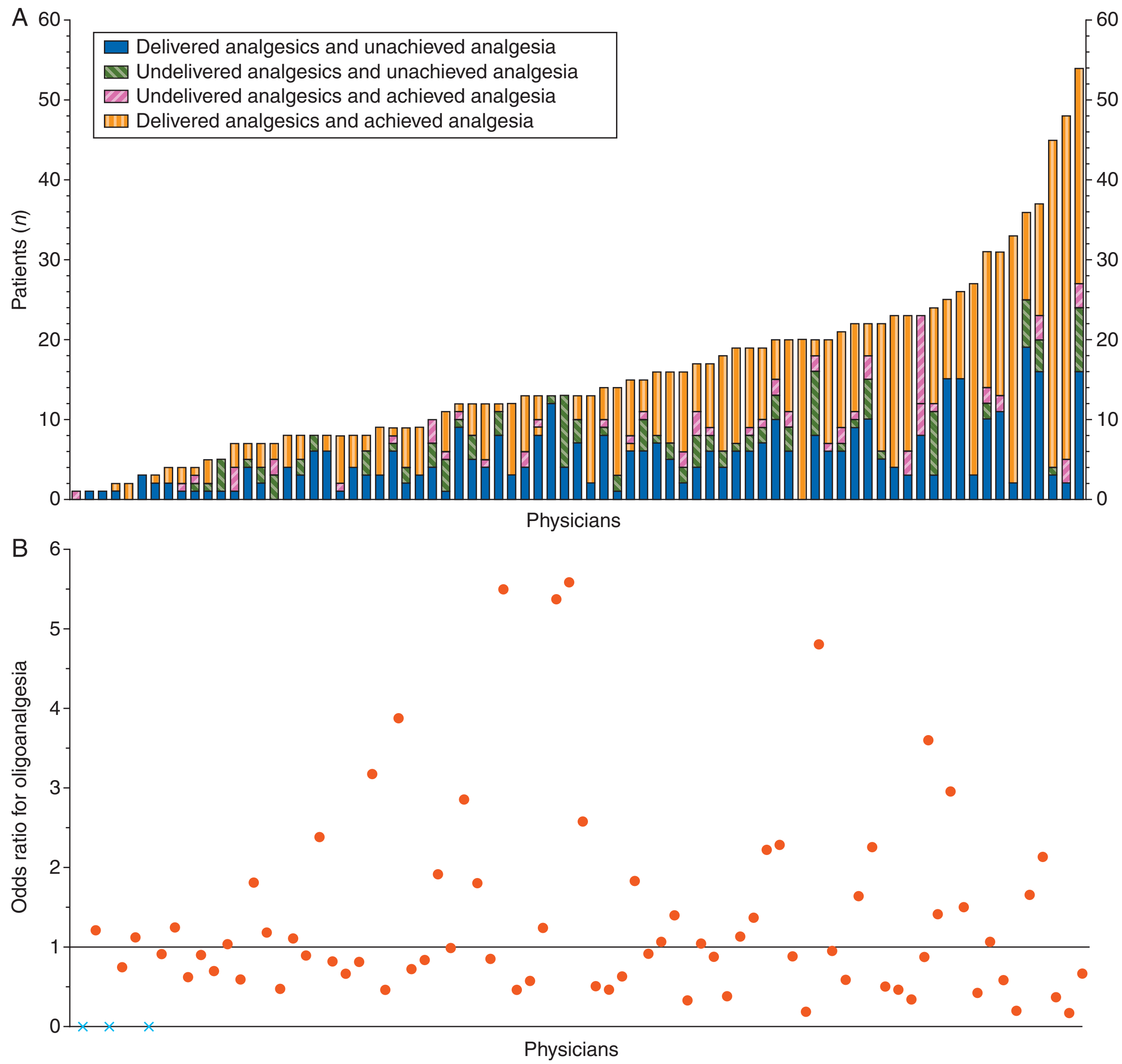

Fig 3 (A) Analgesic administration and achieved analgesia by each of the 77 physicians. (B) OR for the comparison of each physician with an 'average physician' after adjustment for observed patient's and physician's characteristics. x, missing value.

also more common in patients with more severe injuries, as reflected by higher NACA scores. In these critical situations, priority may rightly be given to restoring vital functions rather than to relieving acute pain.[7]

Finally, patients who did not receive any analgesics were nearly nine times as likely to suffer from oligoanalgesia in our multivariable model. Our data suggest that an NRS $\geq$6 serves as a treatment threshold for physicians who reserve the administration of fentanyl for more severe pain. Unrelieved pain is also a reflection of patients' attitudes towards pain and its treatment; many patients do not spontaneously request analgesics,[7] or refuse them altogether.[6] Unfortunately, patient request for, or refusal of, analgesics was not recorded in our study.

Our study has some limitations, despite the fact that the retrospective study design allowed the inclusion of a high number of physicians and patients. First, causation between patients' or physicians' characteristics and oligoanalgesia cannot be ascertained. However, our findings are both concordant with other clinical studies and supported by research in the field of social cognition. Secondly, since physicians' characteristics available in a retrospective study are limited to general descriptors, significant unexplained context heterogeneity remains. Nevertheless, we found a significant cluster effect. Thirdly, since our study involved only one prehospital system, our findings may not be generalized to other settings. However, the long time span and the large number of physicians and patients are a source of

Table 3 Multivariate model of oligoanalgesia. Model also adjusted for the respiratory rate and oxygen saturation at the scene. NACA, National Advisory Committee for Aeronautics numeric rating score; NRS, numeric rating scale; MOR, median odds ratio; IOR, interval odds ratio. *For each 1-point increase on the NRS over 4

		95% IC	*P*-value
Fixed-effects variables, varying within cluster			
Gender			
Female	Reference	—	—
Male	1.4	0.99–2.0	0.055
Unrelieved pain	8.8	5.1–15.2	<0.001
NACA score			
II	Reference	—	—
III	1.7	0.8–4.0	0.184
IV	1.9	0.8–4.4	0.118
V	4.4	1.6–12.2	0.004
NRS at the scene	1.50	1.4–1.7	<0.001
Physician female gender	2.0	1.0–4.0	0.039
Physicians' post-graduate experience (yr)			
>5.0	Reference	—	
>4.0to ≤5.0	1.3	1.0–1.6	0.038
>3.0to ≤4.0	1.6	1.0–2.4	
>2.0to ≤3.0	2.6	1.1–6.5	
≤2.0	16.7	1.2–227	
Fixed-effects variables, constant within cluster			
Physicians' post-graduate experience IOR (yr)			
>5.0	Reference		
>4.0 to ≤5.0	0.2–8.0		
>3.0 to ≤4.0	0.3–9.9		
>2.0to ≤3.0	0.4–16.4		
≤2.0	2.7–104		
Physician female gender	0.3–12.7		
Random effects			
Physicians' MOR	2.6	2.2–3.0	

heterogeneity that may improve the generalization of our results. Fourthly, our data included patients up to the end of 2006, and clinical practices might have changed over the 5 yr since that time. However, our data did not show any trend for less oligoanalgesia over the 10 yr studied, and the medical literature has not reported a reduction of prehospital oligoanalgesia in recent years. Lastly, physicians' and patients' race have been sources of disparities in pain management in the past.[29] Race is not reported here for two reasons. Not only does Swiss law disallow documenting race or ethnicity in medical charts, but the vast majority of the Swiss population are Caucasian. Therefore, we believe that race was not a confounder in our study. Further prospective studies are needed to explore physicians' characteristics associated with practice variations, and to test intervention to reduce these variations.

In conclusion, our study demonstrates that prehospital pain management is characterized by ongoing oligoanalgesia due to a combination of undelivered and delivered but unachieved analgesia. The treatments were highly variable among physicians, suggesting that the decisions about if and how to treat acute pain as a result of trauma is a product of complex factors involving situational factors and characteristics of both patients and physicians. The reduction of physicians' variations in the administration of analgesics appears as a valuable target to reduce oligoanalgesia in adult trauma patients.

Declaration of interest

None declared.

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Appendix 1: Detailed statistical analysis

Our data have a hierarchical structure with regard to analgesia; the individual (level 1) interventions are nested within a cluster of physician (level 2) interventions. Therefore, multilevel logistic regression analysis was used.[1 2] Potential predictors of the primary outcome at level 1 were related to patients' characteristics (i.e. age, gender, location of injury, on site time, ISS, NACA score, pain severity, vital signs, etc.). Level 2 variables were related to physicians' characteristics, and included both measured characteristics such as clinical speciality, years of experience, gender, and unmeasured characteristics (or contextual factors) such as skill and environmental context of the interventions.

The analyses were performed using the available data. Plausible interactions between the predictors were assessed and adjustments were made for cluster means.[3]

We started with a model that included all possible prognostic factors with appropriate transformation for continuous variables. We then applied a backward elimination procedure with a conventional 5% level to select a parsimonious prediction model.[4]

The impact of level 2 unmeasured characteristics (contextual factors) was quantified using the MOR, whereas the IOR was used to assess the importance of level 2 measured characteristics.[5] The MOR allows quantifying contextual effects on the same scale (i.e. the OR) as individual variables and is, therefore, more intuitive than the ICC. The MOR equals 1 when there is no variation between clusters, and gets progressively larger as the between-cluster variation increases. As neither the variance nor the distribution of the MOR is known, nested studentized Bootstrap (Bootstrap-*t*) confidence intervals were calculated.[6] The IOR allows contrasting the magnitude of context in level 2 residual variations (i.e. unexplained context heterogeneity) with the variability explained by cluster level variables (physicians' characteristics), and is therefore a measure of the importance of these variables. The IOR interval is narrow when the residual between-cluster variation is small, and wide otherwise. When the IOR interval contains the value 1, the cluster residual variability is large in comparison with the variability explained by the cluster-level variables; if the interval does not contain the value 1, the effect of the cluster-level variable is large in comparison with the unexplained between-cluster variation.[5] The interpretation of level 1 model coefficients is similar to that of standard logistic regression, namely, adjusted log OR, except that the level 1 OR must be interpreted as cluster-specific ORs (i.e. ORs calculated within a cluster).[7] On the other hand, level 2 coefficients are best interpreted using the IOR, as unmeasured heterogeneity between clusters preclude conventional OR interpretation.[5]

Estimations were made using maximum likelihood. Goodness-of-fit analyses were performed using Q–Q plots for the estimated random effects, the Hosmer–Lemeshow test, and the area under the ROC curve.[8] Conditional logistic regression was also used to assess the hypothesis of independence between the random effects and the co-variables included in the model (Hausman specification test).[9] All analyses were performed using STATA 11.2 (Stata Corporation).

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Appendix 2: Characteristics of patients with GCS <13 at hospital

Age (yr)	Gender	GCS on scene	GCS at hospital	Fentanyl (μg)	Ketamine (mg)	Benzodiazepines	Vehicle extraction	Hospital diagnoses	Reason for GCS decline	Intubation at hospital
71	Male	15	3	300	40	Yes	Yes	Femur and tibia fractures	Sedation	No
47	Male	15	3	200	100	No	Yes	Femur and tibia and ankle fractures	Sedation	No
58	Male	14	5	0	175	Yes	Yes	Femur fracture, haemothorax, face laceration	Sedation	No
35	Male	15	10	50	200	Yes	Yes	Femur and ankle fractures, frontal laceration	Sedation	No
68	Male	15	10	0	40	Yes	No	Mandible fracture, tibial laceration	Sedation	No
79	Female	15	10	0	25	Yes	Yes	C1 fracture, rib fracture, tibia fracture	Sedation	No
58	Male	15	10	100	0	Yes	No	Cerebral contusion, ulna fracture	Traumatic brain injury	No

Continued

Continued

Age (yr)	Gender	GCS on scene	GCS at hospital	Fentanyl (μg)	Ketamine (mg)	Benzodiazepines	Vehicle extraction	Hospital diagnoses	Reason for GCS decline	Intubation at hospital
28	Male	15	12	350	0	Yes	No	C2 fracture, lung contusion, tibial fracture	Sedation	Yes
20	Male	14	12	50	0	No	Yes	Cerebral contusion, lung contusion	Traumatic brain injury	no
61	Male	15	12	50	50	Yes	No	Ankle fracture	Sedation	No
28	Male	13	12	0	25	Yes	Yes	subarachnoid haemorrhage, intraventricular haematoma, renal fracture, hepatic contusion	Traumatic brain injury	No
38	Male	15	12	300	100	Yes	No	Femur fracture and tibial fracture	Sedation	No
51	Female	13	12	0	50	Yes	Yes	Liver laceration, femur fracture, rib fracture, wrist fracture	Sedation	No
70	Male	15	12	200	0	No	Yes	Cerebral contusion, rib fractures, elbow contusion	Traumatic brain injury	No

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