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Abstract

Adequate and timely application of analgesics after surgical operations is important from both clinical and economic perspectives. Administering pain relief measures requires information about development of post-operative pain and the effect of analgesics. Such information can be obtained from studying patients' perception of pain in different periods after the operation. This paper applies an ordered response model to a sample of patients undergoing orthopedic surgeries. All studied patients have been received at least one analgesics. The patients' subjective pain levels have been recorded for several intervals up to 24 hours after their respective operations. The adopted statistical model accounts for the unobserved heterogeneity among patients through random coefficients. Such heterogeneity could be due to differences in patients' subjective measure of pain as well as their health status and sensitivity to pain. The analysis indicates that post-operative pain gradually increases over time but with a slightly diminishing rate. The results suggest that analgesics are quite effective in containing the development of pain. However, the analgesic effects manifest gradually, at a rate which is more or less similar to that of post-operative pain. This result implies that the optimal time of administering analgesics is immediately after the operation, suggesting preemptive analgesics could be most effective.

Keywords: *post-operative pain; analgesics; ordered logit; random coefficients*

1. Introduction

The International Association for the Study of Pain, (IASP, 1979) defines pain as "*an unpleasant sensorial and emotional experience associated to present or potential disadvantages for patients*". Pain is not only considered a physiological phenomenon, such as a symptom of a latent or incipient disease, or a consequence of an intervention, but as a pathological state that is likely to evolve to an illness. Neglecting pain might lead to complications in the long run (Dworkin, 1997), a lower quality of life and a longer stay at hospital (Berry and Dahl, 2000). Therefore, tolerating pain in any number of patients could result in considerable economic losses through additional hospitalization costs as well as lower productivity for the patients at least in the short run. The treatment of post-surgical pain has also proved effective in improving the quality of care: patients who have undergone analgesic therapy are reported to experience a better surgical follow up (Berry and Dahl, 2000).

National health organizations throughout the world recognize pain relief as a primordial medical objective – both ethically as well as from a cultural point of view (Zborowski, 1982). Several prevalence studies carried out for the United States, Great Britain and Holland during the 80s and 90s, report that the number of patients suffering from post-surgical pain has grown considerably from 45% up to 79% in all the countries where the surveys have been performed (for a brief review on this topic see Donovan *et al.*, 1987, Visentin *et al.*, 2005). Similar trends have been reported for Italy, where the steps taken against post-surgical pain have been characterized by inefficiencies (*cf.* Notaro *et al.* 2001, Lattuada *et al.* 2004, and Visentin *et al.* 2005). For instance, Italy has historically one of the lowest scores in Europe in consumption of opiates, an indicator of pain relief performance established by the World Health Organization[1].

The level of pain is often considered as an indicator of the quality of care. Every time a patient reports a positive level of pain it could imply that pain is not controlled efficiently and that the clinical procedures should be revised. In this perspective, the "*pain-free hospital*" project (*ospedale senza dolore*) carried out in Italy, among other European countries, provides guidelines that could control the level of pain in the majority of patients complaining of post-surgical pain (Visentin *et al.*, 2005, have estimated the project "pain-free hospital" should achieve the objective of lowering or eliminating pain for 90% of cases. That means that a great number of patients still suffer from a pain that could be avoided through the implementing of such guidelines. However, as Lattuada et al. (2004) reported for a region in Italy, implementing such projects and achieving the stated targets could be difficult in many cases.

Studying the development of post-surgical pain and the effect of analgesics could help improve the administration of analgesics and achieve a better allocation of resources used for pain relief. For instance knowing the evolution of pain, one can better identify the optimal timing of analgesics, or based on the effect of gender, age, type of surgical intervention, one can identify cases that are more sensitive and thus need more help. This study is aimed at modeling the probability of experiencing different levels of post-operative pain as a function of the time after surgery, the time after analgesic therapy, and several patient characteristics. The pain level is modeled using a discrete ordered response model namely, ordered logit. The unobserved heterogeneity among patients is accounted for by random coefficients. The studied sample includes 49 inpatient orthopedic surgeries. The patients were observed in a hospital (*Buccheri La Ferla*) in Palermo (Sicily, Italy), in 2002 and 2003. The analysis is expected to cast light on the impact of individual characteristics and analgesic administrations on the probability of post-surgical pain.

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[1] Italy's poor performance could be explained by the laws that have limited for a long time, the use of narcotics and, at the same time, precluded the use of opiates in clinical practice.

To make such an analysis possible, it is necessary to select appropriate pain assessment tools that could identify the crucial variable that is the level of pain across different cases. Secondly, observations should be frequent in order to monitor every variation in the level of reported pain. In this study observations have been performed over three-hour intervals during the first 24 hours following the operation. The pain level is recorded in five levels from no pain to extremely painful (intolerable level of pain).

The estimation results suggest that the adopted model can be used for selecting an appropriate strategy to control post-surgical pain. In particular, the studied data indicate that time is an important factor in the evolution of pain as well as in the manifestation of analgesic effects. The estimated effect of patient characteristics such as age and gender are consistent with other studies, and can be used for a better allocation of resources among different cases. The model used in this paper can also be used to predict the duration of post-operative pain. To our knowledge, this question has not been addressed in the previous literature thus far. Although the hospital that is subject of this study has not joined "*pain-free hospital*" project, the conclusions of this paper and the adopted methodology can be easily related to other medical units involved in that project or other similar programs.

The rest of the paper is organized as follows. The next section briefly describes the tools employed to assess pain and the methodology applied here. Section 3 presents the data and estimation results. Section 4 concludes the paper with a discussion of the main results and recommendations for further research.

2. Measurement of post-operative pain

Post-surgical pain has been only recently recognized as an outcome measure of care quality. In a seminal paper in 1973, Marks and Sachar first noticed how pain was under-treated. They found a large discrepancy between the amount of analgesics ordered and the amount actually administered to surgical patients, which resulted in significant unrelieved pain. Other studies, carried out after more than 10 years, documented a high incidence of uncontrolled and severe pain in hospitals (Donovan *et al.*, 1987; Oden, 1989). The necessity to develop a precise strategy for pain management has been put in evidence later on, in a work by Kuhn *et al.* (1990), and later stressed in several studies examined by systematic reviews such as Kitson (1993) and Brown (2004).

Post-surgical pain management is complex because of considerable variations among patients regarding pain perception and the intensity and duration of pain as well as patients' characteristics such as type of disease, age and psychological state and differences in nature of surgeries, in

analgesic techniques, and in the actual procedures used in managing pain (Lynch *et al.*, 1997). The need to account for clinical and social factors together with factors due to patients' characteristics has been stressed in a study by Short and Kluger (1998) about post-anaesthetic outcomes. Measures to control pain are based on pre-intervention anesthetics, together with the administration of analgesics after surgery, as soon as pain arises. There are many types of pain medication including opiates or narcotics, local anesthetics, anti-inflammatory medications, and many different delivery methods such as oral, intravenous and epidural administration. Depending on the procedure and clinical situation, a single medication or a combination, and one or more modalities of delivery may be used.[2]

Together with efficiency aspects for physicians and nurses in providing post-surgical assistance, medical literature has underlined qualitative aspects of pain management. Moreover, there is compelling evidence that unrelieved acute pain is directly linked to subsequent long-term pain problems. Unrelieved acute pain complicates recovery and could lead to more complications, longer hospital stays, greater disability and potentially long-term pain (Watt -Watson *et al.*, 1999; Berry and Dahl, 2000; MacLellan, 2004). There is some evidence that extreme suffering from pain could weaken the patient's immune system, while the risk of addiction to pain medication has been shown to be extremely low in patients who received medications for post-operative pain.

Inadequate management of pain not only decreases the quality of life but creates a financial burden on the health care system. A few studies carried out in American hospitals concluded that unrelieved pain could cost millions of dollars annually as a result of longer hospital stays, re-hospitalizations, and visits to outpatient clinics and emergency rooms (Grant *et al.*, 1995; Sheehan *et al.*, 1996). Zimberg (2003) describes some other economic advantages associated to pain management such as saving the additional cost of disability programs because of patients who are unable to work due to pain. The financial burden of analgesics is marginal compared to such considerable benefits for patients and medical units. Chauvin (1998) puts in evidence how there is actually a limited resort to analgesics, in spite of a minimal financial burden and considerable benefits for patients and medical units. Development of an effective pain management plan requires monitoring of the types of analgesic used, pain management regime selected, and knowledge of patients' attitudes. In order to implement such plans, nurses need a minimum level of expertise in pain management and should be able to provide patients with means for describing and assessing their pain.

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[2] As stressed in the AHCPR (1992), an integrated approach to pain management includes cognitive behavioral interventions, systematic administration of appropriate medications, education of both staff and patients, as well as routine assessment of pain. All factors are recommended in order to make progress in providing pain management of a high standard.

Difficulties encountered in measuring the pain and its treatment have been emphasized in medical literature. An extensive review is that of Coll *et al.* (2004). Other studies have highlighted the necessity to interpret patients' needs, in order to correctly assess pain and avoid discrepancies between intensity of pain reported by patients and that reported by physicians and nurses. For instance, Manias *et al.* (2002) report that the nurses' assessment of post-surgical pain could differ from patients' own assessment. It has been observed that nurses tend to over-evaluate pain when it is high and to under-evaluate when it is moderate: such a contrasting evaluation might be due to nurses' personal experiences or to their perceptions about patients' pain (Harmer and Davies, 1998). Pain assessment tools need to distinguish the true suffering patients from patients who are simulating (Torina, 2005). The questionnaires should not be too complicated to fill or misleading, allowing all patients to report correctly their level of pain. Hernandez-Quevedo et al. (2004) describe problems that might occur in reporting bias. Discrepancies across observations might depend either on variables as patients' different income, age, education and personal experience of illness: this means that different groups tend to assess pain within their own specific context, using different reference points when they are responding to the same question. Hence, there could be any index shifts (that occur if the shape of the distribution of health, that is self-assessed remain the same, but there is a change in its location such that a parallel shift in all of the reporting thresholds for particular subgroups of the population is observed) or cut-point shifts (that implies that there is a change in the relative positions of the reporting thresholds). In order to overcome such problems, the authors suggest to apply models such as pooled ordered probit or random effects ordered probit. The literature stresses how pain can only be assessed on an individual basis using self-report pain and external indicators (Brown, 2000). Unfortunately, external indicators are frequently dismissed, as nurses and physicians rely heavily on validated pain assessment scales to assist in the monitoring of the patient's pain.

A wide variety of pain scales have been used in the literature. Assessment scales mostly used include visual analogue scale (VAS) as in Gudex *et al.* (1996) and Fletcher *et al.* (1995)[3], verbal rating scale (VRS) as in Bucknall and Manias (2001), verbal assessment scale (Downie et al., 1978), and finally face expression scale (Torina, 2005), the latter being particularly useful for children. The main limitation of all these scales is in the fact that they offer a unilateral approach to pain assessment, by omitting important factors, including those that may exacerbate or reduce pain and/or cognitive and behavioral changes. These factors include changes in sleeping or eating patterns, increased frustration, agitated or aggressive behaviors or withdrawal from family and

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[3] Fletcher *et al.* (1995) assessed post-surgical pain in a sample of 60 patients who underwent orthopaedic surgery. That study analyses the impact of the timing of certain analgesics, stressing the benefits of analgesics prior to the operation as opposed to post-surgical administration. In our data, the patients did not have any pre-surgical analgesics.

friends or avoidance of activity. However, thanks to their simplicity, the assessment scales are widely used in medical literature.

In this study a VRS with five levels has been used to measure pain. In this method, the patient is offered a set of adjectives, from which she is asked to choose the one that best describes the intensity of her pain. The main weakness of this scale is that it could be affected by the differences in patients' age, language, educational and cognitive status (Bucknall and Manias, 2001). However, VRS measures provide a quick and simple method of pain assessment for acute pain. As we see later, the adopted model in this paper can take into account differences among patients through random coefficients. Nurses and physicians have recorded the assessment scales with regular observations in three-hour intervals during the 24 hours following the surgery, resulting in 8 observations for each patient. Five pain categories from "no pain" to "unbearable pain" have been considered. The observation sheets also include patient's age, gender, time of the administered analgesics and a measure of patient's satisfaction of the quality of care received during the surgical follow up. It should be noted that the analgesics administration during the observation period has not been random. Rather, it has been decided based upon the complexity of the surgical intervention and also the level of pain declared by the patient after the surgery. Therefore, it can be expected that more severe cases are more likely to have earlier analgesics and perhaps repeated treatments.

3. Model specification and estimation methods

Ordered discrete choice models such as ordered logit and probit have been often used for ordered categorical response variables that represent groups of continuous variables, such as income groups. The application of these models can be extended to categorical variables that have an "assessed" order, such as "the extent of pain relief after treatment" (Anderson, 1984). These variables are referred to as assessed, ordered variables. In this paper we use an ordered logit model as explained in Greene (2003) and Wooldridge (2002)[4]. In this model it is assumed that the individual choices are based on a latent variable, which can be considered as a measure of the individual's random utility. This latent variable is defined as a function of explanatory variables. In the context of this study, the latent variable y_{it}^* is defined as the pain level of patient i at period t. The latent variable y_{it}^* is assumed to be a continuous additive function of a vector of time-variant factors denoted by

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[4] Recently, this kind of models have been used in a RAND study assessing patients' use and preferences for information about the technical and interpersonal quality of care delivered by individual physicians (Center of Excellence for the Study of Healthcare Provider Behavior, 2005). See also McKelvey and Zavoina (1975) for an earlier application. To our knowledge, there are few studies applying these models in the context of post-operation pain.

X_{it}, and of a vector of patient's characteristics represented by Z_i. The vector X_{it} includes, for instance, the time period after the operation and the number of hours after the application of analgesics.

Considering the additive stochastic term the latent pain level can be written as:

$$y_{it}^* = \alpha + X_{it}\beta + Z_i\gamma + \varepsilon_{it}, \qquad (1)$$

where subscripts i and t respectively represent a given patient and the number of hours after her operation; α, β and γ are the parameter vectors to be estimated; and ε_{it} is an *iid* stochastic error term that represents the unobserved factors. We assume that patients translate their continuous pain level (latent to us) to a finite number of pain levels (J) asked in the survey. The probability of choosing pain level j is defined as:

$$\Pr(y_{it}=j) = \Pr(\mu_{j-1} < y_{it}^* \le \mu_j) \; ; \quad -\infty = \mu_0 < \mu_1 < ... < \mu_J = +\infty \,, \, j \in \{1,2,...,J\}, \qquad (2)$$

where y_{it} is the discrete response variable, that is patient i's pain level, t hours after her operation; and μ_j's are the threshold parameters. Assuming a logistic probability distribution for the error term ε_{it}, the above probability can be written as:

$$\Pr(y_{it}=j) = \frac{1}{1+\exp(-\mu_j + \alpha + X_{it}\beta + Z_i\gamma)} - \frac{1}{1+\exp(-\mu_{j-1} + \alpha + X_{it}\beta + Z_i\gamma)}, \qquad (3)$$

that can be estimated using the maximum likelihood estimation method.

In the above model it is assumed that all individual patients use a similar measure of pain. This is a restrictive assumption in that individuals differ with respect to their sensitivity facing pain. Moreover, a given patient's perception of pain could vary depending on her expectation regarding the seriousness of her operation. For instance a patient with a complex operation could complain less than a similar patient who had a relatively simple operation but who suffers the same level of pain. This restrictive assumption can be partly relaxed by considering that the intercept parameter α varies across different individuals. Moreover, the effect of independent variables X_{it} could also vary across patients. For instance, the development of pain after the operation and the effect of analgesics depend on the type and complexity of the operation as well as other unobserved patient characteristics. Such unobserved heterogeneity can be partly accounted by randomizing coefficient vector β across patients.

Assuming that α and β are normal random variables across patients, the model in Equation (1) can be written as:

$$y_{it}^* = \alpha_i + X_{it}\beta_i + Z_i\gamma + \varepsilon_{it}$$
$$\alpha_i \sim N\left(\alpha, \sigma_\alpha^2\right) \qquad\qquad (4)$$
$$\beta_i \sim N\left(\beta, \sigma_\beta^2\right)$$

and equation (3) is changed by substituting α and β with α_i and β_i respectively, resulting in:

$$\Pr(y_{it} = j) = \frac{1}{1+\exp(-\mu_j + \alpha_i + X_{it}\beta_i + Z_i\gamma)} - \frac{1}{1+\exp(-\mu_{j-1} + \alpha_i + X_{it}\beta_i + Z_i\gamma)}. \qquad (5)$$

As the likelihood function of the above model does not have closed form, the model with random coefficients can only be estimated using the Maximum Simulated Likelihood Method. In this method the log-likelihood function is approximated by Monte Carlo simulation technique, which consists of integrating the conditional log-likelihood function (conditional on random coefficients) with random draws for the random coefficients. In order to avoid a very large number of draws, the pseudo-random Halton procedure has been used. Halton draws have proved to be more efficient than truly random draws (Bhat, 2001, Heshner and Greene, 2003). The *LIMDEP* software (Greene, 2002) has been used for the estimations. We have considered several numbers of draws. The results indicate that the estimations are not sensitive to the number of draws at more than about 1000 draws.[5]

As seen in Equation (2), the probability of choosing a certain pain category is assumed to be a function of a continuous latent variable (y_{it}^*) that can be considered as the patient's pain level. Ordered logit model is a proportional odds model in the sense that the odds ratio of switching from an alternative to the next one is invariant to the alternative. Namely, the probability ratio $\dfrac{\Pr(y_{it}^* > \mu_j)}{\Pr(y_{it}^* \le \mu_j)}$ is shown to be equal to: $\exp(\alpha_i + X_{it}\beta_i + Z_i\gamma)$, thus not a function of the actual pain category j.[6] This assumption implies that for any given patient, as long as the independent variables remain unchanged, the probability of moving up one level in the pain categories does not depend on the actual pain category.

In this paper, we consider both the simple model with constant parameters as in (1) and the alternative model with random coefficients as expressed in (4). The patient characteristics included in the model (Z_i) are gender, age with six cohort dummies, a dummy variable indicating whether more than one analgesic have been used, and a dummy variable controlling for the quality of care (poor or acceptable) as perceived by the patient.

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[5] We have found that mainly coefficients that were not statistically significant show rather sensitive to the changes in the number of draws. This can probably be explained by the relatively small size of the sample.

[6] Anderson (1984) proposes a generalized ordered logit model that relaxes the proportional odds assumption. He argues that such a model is preferable in cases where ordering is not *a priori* obvious.

The time-variant explanatory variables (X_{it}) include the number of hours after the operation and the number of hours elapsed after the analgesic as well as their respective squares. Considering this specification, the adopted model is based on the assumption that after controlling for observed patient characteristics and stochastic errors, the evolution of pain level ($y*$) follows a quadratic function of the following form:

$$y_t^* = y_0^* + \theta_1 t + \theta_2 t^2 + \omega_1 s + \omega_2 s^2, \tag{6}$$

where $\theta_1, \theta_2, \omega_1$ and ω_2 are the parameters to estimate; y_t^* and y_0^* are respectively the pain level at t and the initial pain level at $t=0$ (right after the operation); and s is the time elapsed after the analgesic (or after the most recent analgesic for patients with several analgesics). Note that in the random coefficient model explained above, the pain function (6) is assumed to be patient-specific, that is parameters $\theta_1, \theta_2, \omega_1$ and ω_2 vary across individual cases.

4. Data

The questionnaire for monitoring pain includes the following information: name, age, sex, type of surgery, level of pain at the end of the operation, level of pain in the hours following the surgery, quality of care with optional comments. The questionnaire has been filled by physicians (anesthesiologists) and nurses. Data have been collected in years 2002 and 2003, in the surgical division of orthopedics department at "Buccheri La Ferla" hospital in Palermo, Italy.

Patients who have been administered a continuous analgesic such as epidural or femoral, have been excluded. Hence, the patients considered for the final estimations have been treated with one of the following analgesics: Diclofenac; Meperidina; Paracetamolo; Tavor; Toradol (tromethamine ketorolac). Such analgesics are very commonly used in the treatment of post-surgical pain, do not have severe contraindications and are immediately available from the pharmacy at the hospital.

The type of analgesics is constant for each given case and has been selected based on the complexity and type of the operation as well as the patient's individual medical data. We assume that these analgesics have a similar appeasement effect. Given that different analgesic types might have completely different time-effects, the above assumption may be restrictive. However, since the random coefficients vary across individual patients, they could capture these differences to the extent that the time effects can be modeled with the same functional form for all the above analgesic types.

The final sample consists of 49 orthopedic cases including 24 male and 25 female patients with an overall average age of 59.6 years old. The patients' age varies from 15 to 86 years old for men and 22 to 89 for women with a median value of 67 for both male and female patients.

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Several factors might influence intensity, characteristics and length of post-surgical pain. One can consider the complexity of surgical intervention, its duration, patients' psycho-physiological conditions and the quality of preparation. In spite of a low level of pain immediately after the operation, pain could develop with greater intensity in the following hours.

The pain level is defined in five categories labeled from 0 (no pain) to 4 (intolerable pain). Collection of data has been done through questionnaires. Patients have been interviewed by an anesthetist together with a nurse. They have been told about the studies that would have been carried out using the information provided, stressing the relevance that this could have for quality of care. Patients have been asked about how they would have categorized the level of pain and the quality of care received. While the latter has been classified into three levels (poor, good and very good), level of pain has been categorized into five levels: Level 0 corresponds to no pain at all, at rest or in movement; level 1 indicates no pain at rest, but slight pain while moving; level 2 represents slight pain at rest and high pain in movement; level 3 indicates high pain at rest and intolerable pain when moving; and finally, level 4 means intolerable pain even at rest.

Table 1 summarizes reported values for pain as monitored at three-hour intervals after the operation. As this table indicates, most patients do not declare any pain immediately after the surgery, which is an expected outcome because of the effects of anesthesia. Table 1 also lists the number patients that had analgesics. These numbers show that in most of the cases, patients do not receive analgesics within a several hours after their operation. In total 60 analgesics have been administered to the patients in the sample, most of which have been performed about 12 to 18 hours after the operation.

[Table 1 here]

As it is seen in the table, the maximum value of pain is often limited to level 2 that is, slight pain at rest and high pain at movement. The peak in the level of pain (increase in the number of patients declaring a level of pain higher than 1) arises in the time interval between 6 to 12 hours after the surgery. Number of patients declaring a level of pain more than 2 increases from 10 to 15 in these time intervals. Pain rises again for some patients 18 hours after the surgery (4 patients declare to feel intolerable pain (level 4) and ask for further analgesics. In some of these cases the previous analgesic might have had no effect or its effect might have vanished. Overall, the observation of maximum pain level is quite rare. To avoid the problem of small sample, these values, that are limited to 2.6 percent of the observations, are stacked to the next lower level (level 3).

Patients' subjective assessment about the quality of care is described in three categories: poor, good and very good. However, most patients have assessed a good quality. Only five patients reported a poor quality and only 2 assessed a very good quality. We constructed a new dummy variable

(POOR) that takes 1 if the care is evaluated as bad and 0 otherwise. As mentioned earlier, the following patient characteristics are also included in the model: dummy variable MALE for patient's sex, age dummies in 6 categories, and a dummy variable (REPEAT) that takes 1 if the patient has received more than one analgesics during the sample period and 0 otherwise. T_SURG is the number of hours after the operation and T_ANAL is the number of hours after the administration of the most recent analgesic. A descriptive summary of the variables included in the analysis is provided in Table 2.

[Tables 2 here]

5. Estimation results

The estimation results are listed in Table 3. Comparing the estimated coefficients across the two models indicate significant differences between corresponding coefficients, suggesting that ignoring the unobserved heterogeneity across patients could create significant biases in the estimated parameters. As it can be seen in the tables, in the mixed models with random parameters, the standard deviation of virtually all the random coefficients is statistically significant. Moreover, the significant variations in the coefficients of the time variables suggest that the development of pain and the effect of analgesics vary depending on the case.

[Table 3 here]

As Table 3 shows, the results suggest that male patients show lower pain levels compared to female cases. This result is consistent with the findings of medical literature, according to which the way men and women experience pain is different.[7] More importantly, the positive effect of time after surgery suggests that the pain increases with time at least within the 24 hours period recorded in the data. The negative coefficient of the square term indicates however, that post-operative pain increases at a decreasing rate. On the other hand, the negative and significant effect of time after the analgesics suggests that these interventions are effective in lowering pain, but that their effects appear gradually. Here, the second order effect is positive, suggesting that the appeasing effect diminishes with time.

The main result of this analysis is that time is an important factor in pain relief. Table 3 shows that the coefficient of T_ANAL is lower in absolute value than that of T_SURG, whereas the coefficients of the corresponding square terms are more or less similar in absolute values. This

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[7] Some of the differences between men and women in responding to pain and analgesics are documented in Levine et al. (1998).

suggests that the analgesics will be most effective if they are administered as early as possible that is, immediately after the operation or possibly even a few hours prior to the operation.

Age variables show a peculiar effect on pain level, which cannot be explained clearly. For instance, while groups of 40-49, 50-59 and those older than 80 years old feel more pain than patients younger than 40 years old, patients aged between 60 and 80 develop more pain than the youngest group but less pain than the middle age patients. These results could suggest that age variables actually capture other unobserved differences across patients. Given the limited number of patients in the sample and the relatively high variation within each age group, the present data cannot provide reliable information about the age effects. The results also indicate a positive effect for repeated analgesics but this effect is not statistically significant in eth random-coefficient model. The positive effect in the first model can be explained by the higher severity of the case where repeated analgesics were applied, which is partly captured by the random coefficients in the second model.

The results in Table 3 also suggest that subjective quality has a negative impact on pain level: however, it is a tautological result that patients who reported a poor quality of care must have experienced a higher pain. It is also possible that in the patient's assessment about care that is the psychological factors linked to nurses' and physicians' assistance have conditioned the perception of pain.

The estimated marginal effects at the sample mean are provided in Table 4. In general, these estimates suggest that the marginal effect of virtually all the variables has a lower magnitude for high levels of pain. This might suggest that in lower pain levels, a larger fraction of variation in pain can be explained by the explanatory variables. Particularly, this can be considered as suggestive evidence that analgesics can be more effective when pain is moderate.

4. Conclusions

This study has been aimed at modeling the development of post-surgical pain for a sample of 49 orthopedic patients who underwent surgery in the period 2002-2003. The probability of patients to experiment a certain level of pain has been estimated using an ordered discrete choice model. Two alternative models have been considered: a simple ordered logit model and a mixed ordered logit model with random parameters. The latter model considers some of the unobserved factors, especially those related to differences in pain perception among patients. The evolution of pain has been considered with two main time variables measuring respectively the time after the operation and the hours elapsed after the administration of the analgesics.

The results indicate that the perception of pain and the analgesic effects might vary across individual cases. This paper shows that such unobserved heterogeneity can be partly taken into account using random coefficient models. The present analysis also highlights the effect of patient characteristics such as gender.

The results suggest a significant appeasing effect for analgesics. The analysis shows that time has a crucial effect in the development of the post-operative pain as well as the analgesic effects: both these effects appear gradually but at a decreasing rate. The results also suggest that pain can be lowered considerably or, in some cases, prevented altogether if the analgesics are applied in a timely manner. The results of this paper suggest that analgesics are most effective if they are administered as early as possible after the operation.

The present paper is a contribution in investigating the development of post-surgical pain. Moreover, information obtained by this study can be useful for physicians and nurses in developing an effective strategy in the management of pain. As a result, there could be an improvement of care, savings in resources and a better health outcome.

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Table 1 – Distribution of patients by pain level and by time after surgery

Level of pain	HOURS AFTER SURGERY							
	3 h	6 h	9 h	12 h	15 h	18 h	21 h	24 h
0	39	38	28	23	23	24	23	22
1	9	9	11	14	11	13	14	16
2	1	2	6	7	6	5	4	10
3	0	0	2	3	8	5	4	1
4	0	0	2	2	1	2	4	0
Total number of patients	49	49	49	49	49	49	49	49
Patients that had an analgesic	1	1	7	27	8	5	10	1

Table 2 – Descriptive statistics (392 observations from 49 patients)

	Mean	Standard dev.	Minimum	Maximum
LEVEL OF PAIN	0.717	0.97	0	3
T_SURG	13.50	6.88	3	24
T_ANAL	6.29	4.41	3	24
REPEAT	0.163	0.37	0	1
MALE	0.490	0.5	0	1
Age	59.6	20.5	15	89
AGE 30_39	0.082	0.27	0	1
AGE 40_49	0.122	0.32	0	1
AGE 50_59	0.102	0.30	0	1
AGE 60_69	0.143	0.35	0	1
AGE 70_79	0.245	0.43	0	1
AGE > 80	0.184	0.38	0	1
POOR	0.102	0.30	0	1

Table 3 – Estimation results

	Model with constant parameters	Model with random parameters	
	Coefficient	Coefficient's Mean	Coefficient's Std. Dev.
T_SURG	0.489** (0.088)	0.643** (0.0704)	0.0956** (0.0077)
T2_SURG	-0.0109** (0.0031)	-0.0182** (0.0024)	0.00006 (0.0003)
T_ANAL	-0.473** (0.117)	-0.468** (0.0896)	0.2029** (0.017)
T2_ANAL	0.0182** (0.0052)	0.0147** (0.0040)	0.00007 (0.0008)
REPEAT	0.903** (0.315)	0.0188 (0.258)	
MALE	-0.839** (0.225)	-1.264** (0.194)	
AGE 30_39	0.334 (0.577)	1.209* (0.497)	
AGE 40_49	1.748** (0.492)	4.174** (0.457)	
AGE 50_59	1.913** (0.511)	4.168** (0.470)	
AGE 60_69	0.969* (0.499)	1.115* (0.445)	
AGE 70_79	0.937* (0.450)	2.079** (0.397)	
AGE > 80	1.806** (0.4549)	3.266** (0.407)	
POOR	2.077** (0.400)	2.545** (0.320)	
CONSTANT	-3.556** (0.707)	-5.522** (0.591)	1.129** (0.102)
Threshold parameters			
μ_1	1.682** (.141)	2.635** (.128)	
μ_2	3.014** (.220)	4.329** (.199)	

* Significant at 5%; ** Significant at 1%.
Standard errors are given in brackets.
The dependent variable is the level of pain in four categories from zero to 3.

Table 4 – Marginal effects estimated at the sample mean

Simple ordered logit model	Y=0	Y=1	Y=2	Y=3
T_SURG	-.1200	.0667	.0362	.0170
T2_SURG	.0027	-.0015	-.0008	-.0004
T_ANAL	.1161	-.0646	-.0351	-.0165
T2_ANAL	-.0045	.0025	.0013	.0006
REPEAT	-.2219	.0988	.0805	.0426
MALE	.2030	-.1112	-.0621	-.0297
AGE 30_39	-.0830	.0426	.0271	.0133
AGE 40_49	-.3983	.1040	.1757	.1187
AGE 50_59	-.4237	.0865	.1944	.1428
AGE 60_69	-.2373	.1014	.0882	.0476
AGE 70_79	-.2299	.1076	.0806	.0417
AGE > 80	-.4153	.1247	.1761	.1145
POOR	-.4494	.0739	.2101	.1654
Random coefficient ordered logit model	Y=0	Y=1	Y=2	Y=3
T_SURG	-.1439	.1219	.0176	.0043
T2_SURG	.0036	-.0031	-.0004	-.0001
T_ANAL	.1048	-.0889	-.0128	-.0031
T2_ANAL	-.0033	.0028	.0004	.0001
REPEAT	-.0042	.0036	.0005	.0001
MALE	.2755	-.2307	-.0360	-.0088
AGE 30_39	-.2915	.2236	.0539	.0140
AGE 40_49	-.7177	.1511	.3627	.2038
AGE 50_59	-.7054	.1216	.3669	.2169
AGE 60_69	-.2672	.2105	.0452	.0115
AGE 70_79	-.4757	.3476	.1008	.0273
AGE > 80	-.6613	.3359	.2407	.0846
POOR	-.5513	.3141	.1803	.0569

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