Continuous assessment of labour pain using handgrip force

N Wickboldt MD1, 2, Georges Savoldelli MD2, Benno Rehberg-Klug MD2

The current standard of pain assessment is rating scales such as the visual analogue scale (VAS) or the numerical rating scale (NRS). This type of evaluation has been shown to be highly effective when pain is relatively stable over a certain time frame, even for short durations, such as in postoperative pain. However, for highly dynamic situations in which pain intensity can change from one minute to the next, the use of such scales is challenging and problematic because each assessment requires an interaction between the patient and the caregiver.

Examples of such dynamic situations include surgical, interventional diagnostic or therapeutic procedures. Many of these procedures are currently performed using continuous infusions of the short-acting opioid remifentanil. Another prototypical example of dynamic pain intensity is labour. During labour, pain changes rapidly from absent to minimal pain between contractions to very intense pain during contractions.

Although epidural analgesia is currently considered to be the gold standard of analgesia during labour (3–4), remifentanil patient-controlled analgesia (PCA) is increasingly used as an alternative (5–7). To optimize remifentanil PCA for labour pain, or other uses of remifentanil PCA, a continuous feedback of pain intensity would be advantageous. In addition, during labour, a method to predict future contractions would be useful to determine the optimal moment for remifentanil bolus administration to correlate the symptom (pain) with its treatment (the peak effect of remifentanil). A continuous evaluation of pain during labour would require the possibility to construct a time series of onset and cessation of pain during contractions. This time series could be used to create a mathematical model of intercontraction intervals and to predict the occurrence of future contractions. This prediction of the onset of a future contraction may then be used to guide the application of remifentanil bolus.

1Department of Adult Intensive Care Medicine at Royal London Hospital, Barts Health NHS Trust, London, United Kingdom; 2Service d’Anesthésiologie, Hôpitaux Universitaires de Genève et Faculté de médecine, Université de Genève, Genève 14, Switzerland

Correspondence: Dr Nadine Wickboldt, Service d’Anesthésiologie, Département APS1, Hôpitaux Universitaires de Genève, Rue Gabrielle-Perret-Gentil 4, CH-1211 Genève 4, Switzerland. Telephone 41-223727402, fax 41-223823058, e-mail nadine.wickboldt@hcuge.ch

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The simplest way to obtain a continuous pain evaluation would be to use an electronic version of a pain scale, as previously tested in volunteers (6,9). This electronic pain scale requires patients to simply use a slider or cursor to indicate their pain level. There are, however, two disadvantages of this method. First, the patient needs to concentrate continuously on the scale to position the cursor at a level corresponding to his subjective pain experience. Second, there is an inherent danger that the patient leaves the cursor in a position indicating severe pain when the pain has already subsided. When using the signal to guide for example remifentanil administration, this could be deleterious.

Therefore, we aimed to test a system which automatically resets to zero when there is no input from the patient. We tested the possibility to use handgrip force measured by a dynamometer to continuously signal pain intensity as handgrip force has been demonstrated to correlate with descriptors of pain intensity in volunteers (10).

In the present study, we investigated the use of continuous pain evaluation with the dynamometer in parturients. The objective of the study was to evaluate whether monitoring of pain during labour using handgrip force is possible and will allow assessment of pain intensity during contractions. Therefore, we compared different parameters of the pain assessment by handgrip force (peak force, mean force, duration of pain during contractions, area under the curve of force measured during a contraction) in terms of their correlation with pain assessment using a standard NRS.

METHODS

Ethics approval for the present study was provided by the Ethical Committee NAC of Geneva University Hospitals, Switzerland (HUG 12-077).

Setting

Geneva University Hospital, Switzerland, is a primary and tertiary care centre with the largest obstetrical department in Switzerland (>4000 deliveries/year).

Neuraxial analgesia (combined spinal-epidural) is commonly used by parturients (>85%) and only a small fraction of patients benefits from a remifentanil PCA for various reasons (eg, contraindication of regional anesthesia in the presence of coagulopathies, comorbidities, anatomy or maternal wish).

Study design

The study was designed as a single-centre, observational, descriptive study. Because of its exploratory aspect, a priori sample size calculation for the present study was not possible.

Inclusion criteria were parturients >18 years of age, American Society of Anesthesiologists (ASA) physical status <3, ability of the participant to read and understand the information sheet and to sign and date the consent form, and status at the beginning of labour before requesting spinal-epidural analgesia. In the authors’ institution, parturients are admitted to the delivery room when regular contractions are measured by parturients (>85%) and only a small fraction of patients benefits from a remifentanil PCA for various reasons (eg, contraindication of regional anesthesia in the presence of coagulopathies, comorbidities, anatomy or maternal wish).

Exclusion criteria were parturients with complicated pregnancies (preeclampsia or abnormal placentaent), contraindication to neuraxial anesthesia (history of clotting disorders, sepsis, local infection at the injection site, spinal malformation) and late-stage labour with severe pain necessitating the initiation of epidural analgesia within the hour following admission.

Subject recruitment and screening

On admission to the delivery room, approximately 1 h before the planned beginning of the study procedure, the parturient was informed by one of the investigators about the study. Written informed consent was obtained immediately before the beginning of the study procedure by one of the investigators.

Fifty parturients were screened for the study and seven did not wish to participate.

Study procedure

Forty-three parturients were prospectively included during the period from August 2012 to November 2012. The handling of the dynamometer and use of the NRS were explained in detail to the selected parturients. To calibrate the device to individual hand muscle strength, the parturient was asked to press the dynamometer first with an intensity corresponding to moderate pain (5 on a NRS scale of 0 to 10) and then to maximal imaginable pain (10 on a 0 to 10 NRS), with three repetitions for each calibration measurement. Thereafter, women were instructed to compress the dynamometer with a force corresponding to their subjective pain whenever pain occurred, and hold it as long as the pain was present. Recordings were made for 20 min during the first stage of labour when women experienced regular painful contractions, but did not yet require analgesia. Alternative pain management strategies were permitted, such as relaxation techniques provided by a midwife. A second recording was taken during more advanced labour at the time when women requested epidural analgesia.

However, neither the degree of cervical dilatation nor administration of uterotonics drugs (eg, misoprostol, oxytocin) given before or during the recording nor epidural placement were limiting factors for the study. Therefore, the duration of labour before the first recording and between recordings as well as cervical dilatation were variable for each participating parturient. The maximum pain intensity during the contractions before and after epidural catheter placement and at regular time intervals thereafter were evaluated using the NRS by one of the investigators.

The dynamometer (Noraxon Biofeedback dynamometer [Velamed, Germany]) was used in combination with a portable computer to which it was connected via an analogue-digital-interface. The handgrip force (in Newtons, maximum 600 N) measured by the dynamometer was recorded continuously using Signal (CED, United Kingdom). Simultaneously, the external tocographic signal of uterine contractions and an abdominal wall electromyogram were registered.

Data from the present experiment were also used in a study testing different models for the prediction of future uterine contractions (11).

Analysis

Duration of pain during the contractions was calculated as the time (in seconds) starting from the time point of baseline deviation of the dynamometer signal, indicating pain, until return to the baseline when the painful contraction was finished. The interval between contractions was measured as the time between two starting points of the deviation from baseline on the dynamometer signal.

The tracings of handgrip force were compared with the tocographic tracings to evaluate the congruence between contraction and pain. Using the Signal software, peak handgrip force, mean handgrip force and the area under the curve (AUC) of handgrip force during contractions were measured.

For each recording, parturients were asked once to evaluate subjective pain intensity. To compare the subjective pain level with the corresponding pain level obtained by handgrip force via dynamometer, the handgrip force values of all contractions in the recording sequence were averaged. Recordings with <3 contractions were excluded. Statistical evaluations were conducted using GraphPad Prism 4 (GraphPad, USA) and the statistical software R (12).

Pearson’s correlation coefficient r was used for comparison between NRS ratings and the intensity of the parameters derived from the handgrip force. P<0.05 was considered to be statistically significant for all analyses. Normal distribution of the data was tested using the Kolmogorov-Smirnov test. Mean values are reported with their corresponding SDs.

RESULTS

The 43 participating women had a mean (± SD) age of 32±4 years, a mean height of 164±5 cm and weighed 75±11 kg. Twenty-two of the 43 women were nulliparous, and all were singleton pregnancies.
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between 37 to 42 weeks of gestation. Fourteen had received uterotonic drugs (misoprostol, oxytocin) before or during the recording. In 16 of the women, cervical dilatation was still <20 mm when the second recording of pain during contractions was performed.

An example of one of the original tracings obtained via the dynamometer is presented in Figure 1. All contractions recorded by the dynamometer were also shown on the external tocogram; however, the duration of pain during the contraction was shorter (mean ± SD 34±12 s) than the corresponding time period of raised abdominal wall tension (45±14 s).

During the calibration procedure, when parturients were not yet experiencing pain, an imagined pain intensity of 5/10 on the NRS was indicated with a mean (± SD) force of 69±25 N, and an imagined pain intensity of 10/10 with a mean force of 134±35 N. During the actual recordings, forces used by the women were actually much lower. All parturients who consented for the study and participated at the calibration procedure continued with at least one recording period.

During the first measurement before the women requested analgesia, average mean force during contractions was 19±13 N and mean peak force was 39±26 N. The average pain intensity indicated on the NRS during these recordings was 5±2 on a 0 to 10 NRS. During the second measurement, when the parturient requested epidural analgesia, average mean force during contractions was 25±13 N and average peak force was 48±22 N. At this time point, the average pain intensity indicated on the NRS scale was 7±2. Due to the urgency of pain alleviation via epidural catheter insertion (the hospital policy requires epidural placement no later than 30 min after the request of the parturient), the second recording was obtained in only 24 parturients. Therefore, only data from the first recordings were analyzed further. After administration of spinal-epidural analgesia, pain intensity was reduced to approximately 0; therefore, handgrip force was not measured further. The correlations of the

Figure 1) Original tracings of the handheld dynamometer (solid line; in N) and corresponding tocogram (dotted line) for three exemplary parturients (pat 06, 18 and 38) (1A-C)

Figure 2) Correlation of peak handgrip force, duration of pain during contractions, mean handgrip force and area under the curve (AUC) of handgrip force during contractions with numerical rating scale (NRS). Points are averages of at least three contractions for each individual parturient.
handgrip force parameters with pain intensity indicated with the
NRS are presented in Figure 2 and Table 1. The mean handgrip force
during contractions had the highest correlation coefficient \(r=0.67\)
with the NRS, followed by peak handgrip force \(r=0.56\). The AUC
of handgrip force during contractions had a correlation coefficient of
\(r=0.55\), whereas duration of pain during contractions was not signifi-
cantly correlated with pain indicated on the NRS. Due to the small
number of data point differences between the correlation coeffi-
cients, there were no statistically significant differences except
between the correlation coefficients of mean force and duration
(exploratory analysis without prior power calculation, Williams
modification of the Hotelling test, \(P=0.05\)) (13).

**DISCUSSION**

The present study demonstrated the practice ability of using handgrip
force to continuously assess pain intensity during labour pain, which
fluctuates dramatically during contractions, with low or no pain in
between contractions, and high pain intensity during contractions.
Gracely et al (10) observed that time duration and handgrip force
responses to a stimulus correlated highly with responses on ratio scales
of sensory and affective verbal pain descriptors derived from numerical
magnitude estimation respectively.

In the present study, mean handgrip force, rather than the AUC of
handgrip force or peak force, was found to be the parameter that cor-
related best with pain intensity indicated on standard NRS. It should
be noted that differences between correlation coefficients need to be
confirmed by a study with prior power calculation.

The correlation of handgrip force recorded by the dynamometer
with subjective pain level expressed on the NRS was not sufficient to
infer a subjective pain level from a particular force value, but it was
sufficient to assess whether pain is present – i.e., to indicate the
painful time during a contraction. In future studies, whether the
variability in the correlation between NRS and handgrip force arises
from interindividual differences or intraindividual variability should
be investigated.

Understanding of the use of the device may be different in patients
from different socioeconomic or cultural backgrounds. The sample size
in the present study was too small to analyze differences between such
subgroups; this should be evaluated in follow-up studies. Our study did
not include feedback from the parturients concerning the usability of
the device. Such data are needed to evaluate the feasibility of using the
dynamometer in clinical practice.

This dynamometer method is potentially appropriate for the guid-
ance of remifentanil administration during labour, which is superior to a
continuous infusion (13) and a good alternative to neuraxial anal-
gesia in the presence of contraindication for neuraxial blockage
(16,17) or of maternal wish (18). The use of remifentanil, although
not uniformly supported by all available evidence, has become more
popular in the recent years, and in some institutions it is even rou-
tinely used (5,19,20). However, its potential as a potent \(\mu\)-agonist to
provoke adverse effects, as reported recently, must be kept in mind
(21,22). Therefore, it is important to adapt remifentanil dose and
bolus timing to patient’s need. This could be achieved by a method
to predict future contractions to adjust remifentanil bolus applica-
tion, and by adjusting bolus dose to pain intensity. Feedback of the
dynamometer signal to a remifentanil PCA pump may be a way to
improve efficacy and safety of remifentanil dosing.

**SUMMARY**

The present study demonstrated that labour pain may be assessed using
handgrip force measured via a dynamometer. Further studies are
needed to investigate whether this technique may be used to guide
remifentanil titration in situations of very dynamic pain intensity such
as labour pain.

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REFERENCES
1. Jensen MP. Measurement of pain. In: Fishman SM, Ballantyne JC, Rathmell JP, eds. Bonica's management of pain, 4th edn. Media, Philadelphia: Lippincott Williams & Wilkins, 2010:251-70.
2. Turk DC, Melzack R. Handbook of pain assessment. New York: The Guilford Press, 1992.
3. COG: Pain Relief During Labor. ACOG Committee on Obstetric Practice 2004, Number 295.
4. Gogarten W, Van Aken H, Kessler P. Durchführung von Analgesie- und Anästhesieverfahren in der Geburtshilfe. Anästh Intensivmed 2009;50:502-7.
5. Kränke P, Girard T, Lavanhomme P, et al. Must we press on until a young mother dies? Remifentanil patient controlled analgesia in labour may not be suited as a "poor man's epidural". BMC Pregnancy Childbirth 2013;13:139.
6. Hughes D, Hodgkinson P. Remifentanil PCA for labour analgesia. Anaesthesia 2013;68:298.
7. Schnabel A, Hahn N, Broscheit J, et al. Remifentanil for labour analgesia: A meta-analysis of randomised controlled trials. Eur J Anaesthesiol 2012;29:177-85.
8. Boormans EM, van Kesteren PJ, Perez RS, Brolmann HA, Zuurmond WW. Reliability of a continuous pain score meter: Real time pain measurement. Pain Pract 2009;9:100-4.
9. van Wijk AJ, Loobaeo F, Hoogstraten J. Reliability and validity of a continuous pain registration procedure. Eur J Pain 2013;17:394-401.
10. Gracely RH, McGrath F, Dubner R. Ratio scales of sensory and affective verbal pain descriptors. Pain 1978;5:5-18.
11. Rehberg B, Wickboldt N, Jülliet C, Savoldelli G. Can remifentanil use in obstetrics be improved by optimal PCA bolus timing? Br J Anaesth 2015;114:281-9.
12. R Development Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing. Vienna, Austria, 2006. <www.R-project.org> (Accessed July 15, 2012).
13. Kenny D. Testing measures of association. In: Kenny D, ed. Statistics for the social and behavioral sciences. United States of America: Library of Congress Cataloging-in-Publication Data, 1987:270-91.
14. Huang Z, Shyu ML, Tien JM, Vigoa MM, Birnbach DJ. Prediction of uterine contractions using knowledge-assisted sequential pattern analysis. IEEE Trans Biomed Eng 2013;60:1290-7.
15. Shen MK, Wu ZE, Zhu AB, et al. Remifentanil for labour analgesia: A double-blinded, randomised controlled trial of maternal and neonatal effects of patient-controlled analgesia versus continuous infusion. Anaesthesia 2013;68:236-44.
16. Jones R, Pegrum A, Stacey RG. Patient-controlled analgesia using remifentanil in the parturient with thrombocytopenia. Anaesthesia 1999;54:461-5.
17. Thurlow JA, Waterhouse P. Patient-controlled analgesia in labour using remifentanil in two parturients with platelet abnormalities. Br J Anaesth 2000;84:411-3.
18. Roelants F, De Franceschi E, Veyckemans F, Lavanhomme P. Patient-controlled intravenous analgesia using remifentanil in the parturient. Can J Anaesth 2001;48:175-8.
19. Hill D. Remifentanil patient-controlled analgesia should be routinely available for use in labour. Int J Obstet Anesth 2008;17:336-9.
20. Lavanhomme P, Roelants F. Patient-controlled intravenous analgesia as an alternative to epidural analgesia during labor: Questioning the use of the short-acting opioid remifentanil. Survey in the French part of Belgium (Wallonia and Brussels). Acta Anaesthesiol Belg 2009;60:75-82.
21. Pruefer C, Bewlay A. Respiratory arrest with remifentanil patient-controlled analgesia – another case. Anaesthesia 2012;67:1044-5.
22. Bonner JC, McClymont W. Respiratory arrest in an obstetric patient using remifentanil patient-controlled analgesia. Anaesthesia 2012;67:538-40.