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Original contribution

Effect of effort pain after upper abdominal surgery on two independent measures of respiratory function ☆

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Abstract

Study Objective: To determine how effort pain interacts with changing pulmonary function after upper abdominal incisions.

Design: Prospective, case-controlled study.

Setting: Academic teaching hospital.

Patients: 34 ASA physical status I, II, and III patients recovering from elective, major incisional, upper abdominal surgery.

Measurements: Manometry (maximal inspiratory and expiratory pressure) and spirometry (forced vital capacity, forced expiratory volume during the first second, peak expiratory flow) for three postoperative days. Pain scores (Visual Analog Pain Scale; VAS) at rest and after the manometric or spirometric efforts.

Main Results: Effort pain during either manometry or spirometry was greater than pain at rest on the first postoperative day. Maximal respiratory pressure concomitantly recovered with pain during daily efforts (slopes: −0.429 and −0.278% max/mm VAS; $P < 0.05$). Spirometric measurements showed minimal improvement.

Conclusion: The direct relationship between resolution of pain with effort and direct measures of respiratory muscle effort using manometry, but not those obtained less directly by spirometry, suggests that assessing interactions between pain and effort requires a direct, quantifiable measure of effort.

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1. Introduction

As first recognized by Pasteur in 1913, upper abdominal surgery substantially depresses expiratory measures of pulmonary function. The cause was later attributed to impairment of diaphragmatic contraction, which was considered unrelated to pain since abolition of pain did not return the depressed function to preoperative levels [1,2]. It was then realized that this observation had been based on measures of pain at rest (static pain) and that depression of pulmonary maneuvers, especially coughing, may be less related to pain at rest than to pain during the maneuvers (dynamic pain) [3-5]. Pain at rest tends to maintain a stable low level, while pain during movement increases with the intensity of the movement [6]. The present study was designed to measure correlations between various measures of pulmonary function and pain elicited during the test maneuvers.

Spirometry has long been the standard method for estimating postoperative pulmonary dysfunction and its relationship to pain. A meta-analysis of pulmonary function related to various analgesic interventions showed an improvement in pulmonary infection and atelectasis but not in the spirometric measurements related to the use of epidurals [7]. Thus, spirometry used as a surrogate measure did not seem to reflect true clinical outcome, although pain measures in the contributing studies were taken at rest, not during the maneuvers.

We chose to study two independent measures of pulmonary function—spirometry (volume) and manometry (pressure)—and to measure pain during the maneuvers. All patients underwent upper abdominal surgery and received standard postoperative care and analgesia. We selected spirometry and manometry because they are highly standardized, reproducible, and well characterized with respect to age, gender, and body size [8-10]. They also address different aspects of respiratory muscle function: manometry is a quasistatic maneuver (implying respiratory muscles change length only moderately) to spirometry assesses lung volume through its operating range. Manometry may be more sensitive than spirometry in detecting impaired muscular force because spirometry is only partially dependent on effort [10,11]. We wanted to determine whether the "driving" force to pulmonary performance (manometry) would change to the same extent as its "output" measures (spirometry) in relation to pain.

2. Materials and methods

2.1. Patient population

The Massachusetts General Hospital (MGH) Institutional Review Board for Studies on Human Subjects approved this study. Patients at MGH who were scheduled for upper abdomen surgery by major incision were study candidates. Inclusion criteria were men and nonpregnant women aged 18 to 65 years and ASA physical status I, II, and III. Patients were identified from the online operating room schedule and then asked to participate on the morning of their surgery. All patients provided signed, informed consent.

2.2. Pulmonary function testing

Forced vital capacity (FVC), forced expiratory volume during the first second (FEV_1), and peak expiratory flow (PEF) rate were measured using a portable, handheld spirometer (model #2154, Jones Medical Instrument Co, Oak Brook, IL). Patients were instructed to inspire until they could inhale no further, then place the spirometer mouthpiece in their mouth with teeth on the outside and lips sealed tightly around it. Then they were to exhale as hard and as fast as possible for at least 6 seconds and then to inspire as quickly and with as much effort as possible until reaching a maximal inspiration. After testing, the handheld unit was connected to a base station to print records.

Maximum pulmonary inspiratory pressure (MIP) and maximum pulmonary expiratory pressure (MEP) were measured using a digital manometer (Respironics, Inc, Murrysville, PA). The system consisted of two one-way valves isolating inspiratory and expiratory airflow where the manometer was attached, and a 6 inch (15 cm) flexible tube connected to the bidirectional airflow port. It also contained a small (~1.5 mm) tap to prevent oropharyngeal muscles from affecting these measurements [10]. Patients were instructed to breathe quietly; at the end of a normal inspiration, they exhaled slowly until reaching a comfortable lung volume (functional residual capacity). They then placed their lips firmly around the mouthpiece and, for MIP measurements, they inhaled with as much force as possible until they could sustain a constant value for a few seconds. For MEP tests, patients performed an identical maneuver, but after reaching a comfortable exhaled lung volume and placing their lips firmly around the mouthpiece, they exhaled with as much force as possible until they could sustain a constant value for a few seconds.

Only three efforts were performed for either spirometry, inspiratory, or expiratory pressure, with up to one minute rest between each effort [12]. Subjects were verbally encouraged by the investigator to achieve maximal effort with the best reading chosen for analysis. Spirometry was performed first, followed by the inspiratory and expiratory pressure tests, respectively. All pulmonary tests were performed before surgery to define baseline values then repeated on post-operative days one, two, and three, usually in the afternoons. Patients were mostly reclining on postoperative day one and then lying more upright on postoperative days two and three, as they became stronger. Preoperative data were normalized for a predicted value based on age, height, and gender [9] for spirometry or on patient's age, gender, and body surface area [8] for manometry.