Magnesium Levels and Dynamometric Parameters in Relation with Postoperative Fatigue

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Zusammenfassung

In dieser Studie sind die Variationen des Mg in Serum und in den Erythrozyten sowie die Ermüdungswerte und die Zusammenhänge während der postoperativen Zeit untersucht worden. Es wurden sechzig freiwillige Patienten untersucht, die für abdominelle, elektive Chirurgie programmiert waren. Die Messungen der Ermüdung erfolgten über eine subjektive Skala. Die Kraftstudie wurde mit Dynamometern für die Muskulatur der Extremitäten und das Rückgrat vorgenommen. Das Seromagnesium wurde durch Absorptionsspektralphotometrie bestimmt. Während der Ermüdungsgrad und die Seromagnesiumspiegel am neunten Tag der postoperativen Zeit zunahmen, verringerten sich die dynamometrischen Parameter. Am letzten Tag der Postoperationszeit (am 27. Tag) waren die Ermüdungswerte weiterhin hoch und die Beuge- und Widerstandskraft des Arms immer noch niedrig. Zusammenfassend kann gesagt werden, daß Ermüdung und andere objektiven Indizien der muskulären Funktion mit dem Mg zusammenhängen.

Summary

In this study we have investigated the variations of serum and erythrocytic Mg, the fatigue levels and its relation during postoperative period. Sixty volunteer patients programmed for elective abdominal surgery were studied. The measurement of fatigue was carried out by means a subjective scale specifically designed. The study of force was carried out with dynamometers for the musculature of the extremities and rachis. The Mg was calculated in serum by atomic absorption spectrophotometry. While the degree of fatigue and the serum Mg levels increased in ninth postoperative day, the dynamometric parameters decreased. In the later postoperative period (day 27) the fatigue continued to register high levels, elbow flexion force and resistance of the arm were still low. To summarise, fatigue and muscular function indices are correlated with Mg.

Résumé

Au cours de la présente étude, nous avons enregistré les variations des concentrations sériques et érythrocytaires de Mg, le degré d'asthénie post-opératoire et leurs éventuelles corrélations. Nous avons inclus soixante volontaires devant subir une intervention abdominale élective. Le degré d'asthénie a été déterminé à l'aide d'une échelle subjective spécialement conçue et la force musculaire des sujets (extrémités et rachis) a été mesurée grâce à des dynamomètres. La magnésémie a été dosée par spectrophotométrie par absorption atomique. Le degré d'asthénie et la magnésémie ont augmenté le neuvième jour post-opératoire, alors que les paramètres dynamométriques ont diminué. Lors de la période post-opératoire tardive (27ème jour), le degré d'asthénie était encore élevé alors que la force de flexion du coude et la résistance du bras présentaient des valeurs basses. En résumé, l'asthénie et les indices de la fonction musculaire sont corrélés aux taux de magnésium.

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Introduction

Surgical trauma is normally associated with complex metabolic changes and haemodynamic alterations which may lead to organic malfunction such as muscle fatigue [1,2]. The fatigue appears in a progressive form due to various factors such as failures in the energetic and O_2 contribution, alteration of the enzyme activity, electrolyte imbalance, defects in the macro and micronutrient mineral homeostasis etc. [3–5]. An interesting aspect analysed by various researchers, although without conclusive results, is the relationship that exists between muscle fatigue and the homeostasis of magnesium (Mg) ions [4,6,7]. The Mg, which participates in more than 300 enzymes [8] intervenes at a cellular level in all the enzyme reactions which are catalised by ATP and in the majority of metabolic reactions, playing an essential role in neuromuscular excitability, in muscular contraction and in some systems of membrane transport [8–10]. In this way it has been observed lowered isometric muscle strength in patients with hypomagnesemia [11]. Magnesium are essentials for ideal realisation of muscular contraction and, in fact, the appearance of neuromuscular alterations (spasms, cramp and muscular fatigue) are often present in states of deficiency, as occurs during convalescence after serious illness, surgery or infection [7]. The first symptoms of magnesium deficiency are fatigue and abnormal neuromuscular activity [6]. Since the convalescence period is characterized by increased fatigue, which correlates with deterioration in nutritional status [1], in this study we looked at the variations in erythrocytary and serum Mg during convalescence, evaluated the level of fatigue and analysed the relationship between Mg and the level of muscular fatigue during the postoperative period.

Material and Methods

To carry out the research, 60 volunteer patients (36 women and 24 men) were studied, all of them belong to the middle class. Their average weight was

63,5 ± 8,8 Kg and average height 1,56 ± 0,22 m, programmed to undergo elective abdominal surgery. The requisites for inclusion in the study were as follows; they were not to be suffering any kind of illness other than the one for which they were undergoing surgery; they were not to have been undergoing any pharmacological treatment in the previous three months; they were not to have lost more than 10 % of their normal weight in the previous six months nor more than 5% in the previous month; they were to be in an adequate nutritional state; they were not to be suffering any complications in the first 27 postoperative days; they were to display a nutritional rate (PNI = prognostic nutritional status) lower than 40% and have an axilla temperature below 38 °C during the first 72 postoperative hours.

The PNI was calculated with the following equation [12]: PNI (%) = 158 – 16,6 (ALB) – 0,78 (TSF) – 0,20 (TRF) – 5,8 (DH), (ALB = Albumin g/dl; TSF = Triceps Skinfold mm; TRF = Transferrin mg/dl; DH = Cutaneous Delayed Hipersensivity reactivity).

The study was carried out in three states, preoperative (PRE), on the 9th (9–D) and on the 27th (27–D) day of the postoperative period, the latter in out-patients clinic.

The measurement of fatigue (F) was carried out by means of a subjective scale graduated from zero to ten [13]. The grade was obtained after confronting the patient with a series of graphs which displayed typical day-to-day situations of effort.

The study of force was carried out with dynamometers (JAMAR and Bag-Leg-Chest dynamometers, Clifton, New Jersey, USA) for the musculature of extremities and the rachis, and measurements were taken of the force of flexion of the hand (handshake) (FFH), of the elbow (mainly flexion of biceps) (FFE), the force of extension of the rachis (FER), performance of the arm (PA), and the resistance of the arm (the patient sustained a force of 30% of maximum obtained in PA) (RES). The FFH, FFE, FER and PA were isotonic muscular contractions and RES was isometric muscular contraction. All the exercise were applied in all patients.

In the blood samples taken after a period of three hours without food by venopunction (Venojet), haemoglobin (Hb) and haematocrit (Hto) were determined with an autoanalyser and the Mg in serum were calculated by atomic absorption spectrophotometry (Perkin Elmer 272). Erythrocytic Mg was determined as follows: whole blood was hemolyzed by dilution with deionized water, mixed with Vortex and then frozen, after Mg determination in whole blood and plasma, erythrocytic Mg concentration was calculated according (whole blood Mg-plasma Mg x (1 – Hct)/Hct). Total proteins (TP) were determined by colorimetry in an autoanalyser.

As regards statistical analysis, the SIGMA programme was used, and the analysis of variance was applied, and only when this was significant ($p < 0,01$) was a comparison of paired-samples averages taken by a student "t" test. We also used the lineal regression test and correlation between variables.

Results

In tab. 1, the average values obtained for each of the dynamometric variables and of fatigue (X ± SD) in the three stages in which they were determined, are displayed. The degree of fatigue in the 9th postoperative day (9–D) was much higher ($p < 0,001$) than that found in the preoperative period (PRE), falling on the 27th day (27–D) although it still had not recovered the PRE levels, since significant differences existed compared with that state ($p < 0,001$). The dynamometric rates (tab. 1) displayed an evolution similar to that of fatigue, falling significantly on the ninth postoperative day (9–D) ($p < 0,01$), and then later on 27–D to rise to levels similar to those found in the preoperative period. Neither FFE nor RES were completely recovered, for on 27–D of convalescence differences were noted with respect to the preoperative state ($p < 0,01$ and $p < 0,001$ respectively).

In fig. 1 the evolution of the levels of serum and erythrocytic Mg obtained in each phase of the study are illustrated.

Tab. 1: Evolution of fatigue and dynamometric variables (X ± SD) in the three stages of the study. Statistical signification: 9–D y 27–D vs PRE * $p < 0,05$; ** $p < 0,01$; *** $p < 0,001$.

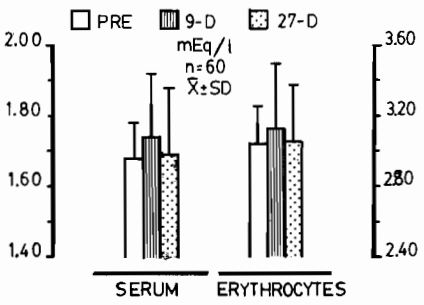
	PRE	9–D	27–D
F (Units)	0,7 ± 0,8	4,4 ± 1,2 ***	1,9 ± 1,4 ***
FFH (Kg)	27,4 ± 9,2	25,3 ± 8,9 ***	26,8 ± 9,2
FFE (Kg)	21,5 ± 6,7	19,2 ± 6,6 ***	20,7 ± 7,1 **
RES (seg)	352 ± 106	234 ± 83 ***	294 ± 105 ***
FER (Kg)	73,2 ± 27,2	56,2 ± 20,2 ***	71,9 ± 26,6
PB (Kg)	22,4 ± 5,3	19,4 ± 5,1 ***	21,1 ± 5,3

FFH, force of flexion of the hand; FFE, force of flexion of elbow;
FER, force of extension of the rachis; RES, resistence of the arm;
PA, performance of the arm.

Tab. 2: Changes in serum Ca and total protein (TP), and hematological parameters: hemoglobin (Hb) and hematocrit (Hto) on PRE and postoperative period (9–D and 27–D) (X ± SD). Statistical differences 9–D y 27–D vs PRE are represented as * $p < 0,05$; ** $p < 0,01$.

	PRE	9–D	27–D
TP (g/l)	7,2 ± 0,6	6,7 ± 0,6 **	7,5 ± 0,5 *
Hb (g/dl)	14,3 ± 4,2	13,0 ± 1,7 **	14,0 ± 1,5 *
Hto (%)	43,0 ± 4,2	39,3 ± 4,4 **	42.0 ± 3,0 *

Fig. 1: Variations in serum and erythrocytic Mg levels before and on postoperative period (9th, 27th day after abdominal elective surgery).



As far as serum Mg is concerned we observed a minor increase in its serum levels on 9–D ($p<0,05$) and a return to initial levels on 27–D after surgery. Erythrocytic Mg remain unchanged in convalescence with respect to preoperatory period.

In tab. 2, haemoglobin (Hb) and haematocrit (Hto) fell on 9–D ($p<0,001$) and later increased their levels on 27–D, although Hb was still at a lower level than PRE ($p<0,01$). Total proteins (TP) also fell in the postoperative period 9–D ($p<0,01$) and rose on 27–D ($p<0,05$).

Discussion

Muscular fatigue has been, for many years, the object of much research. However there still exists much controversy as regards its causes. The period of postoperative convalescence is characterised by an early period of little morbility with an increase of muscular catabolism, accompanied by metabolic and haemodinamic alterations which can cause an imbalance between the nutritive-energetic uptake and the real muscular needs, leading to a state of fatigue [5, 14]. Our results show an increase in the fatigue level in the early postoperative period (9–D), followed by a recovery on day 27 of convalescence, although this seems to be insufficient time to reach the PRE levels. This increase in subjective fatigue coincides with an objective fall in all the dynamometric parameters that give information about performance and muscular resistance, a significant correlation ($p<0,05$) being observed between fatigue (F) and FFH ($r=-0,33$), FER ($r=-0,46$) and PA ($r=-0,31$). *Edwards* et al. [15] have observed disorders in muscular function, particularly in resistence during postoperative convalescence, a phenomenon which has also been discovered in prolongued periods of bed-rest with no surgical intervention, the highest levels of muscular malfunction being reached between the days 8 to 10 of the study. Furthermore we have observed a correlation between the level of fatigue and the RES ($r=-0,37$, $p<0,05$) in the late postoperative period (day 27).

As regards magnesium (Mg) *Stendin-Linberg* et al. [11] suggested a relationship between serum Mg concentration and the maximum voluntary muscle contractions force of quadriceps femoris muscle in man. In our study Mg in PRE is correlated with FFH ($r=-0,27$), FFE ($r=-0,28$) and FER ($r=-0,30$), at 9–D and 27–D of convalescence the correlation between Mg and dynamometric parameters was similar to PRE, and correlation Mg–fatigue (F) increase ($r=0,21$). In the postoperative period Mg rose on 9–D and returned to PRE levels on 27–D, however these changes are not biological importants. These results are in agreement with those observed by *Christensen* and *Kehlet* [1] who indicate that these variations are due to a discharge of Mg from the muscle, caused by a high catabolic rate during the period of convalescence or also to the release of Mg from the damaged tissues. Various authors [7, 8] have showed in normal subjects that stressful circumstances such as surgery, causes a shift of Mg from plasma into red blood cells. Stress caused is capable of inducing Mg deficit by different mechanisms: increase on magnesium diuresis could constitute one cause, and dietary intake of magnesium is often marginal, etc. However the explanations for the precise mechanism remains to be established. Other researchers have described how surgical [6, 16] or exercise and hypoxia [17] stress can provoke an early period of hypermagnesaemia; this may occur as a consequence of a reduction in magnesium excretion and release of magnesium from damaged and affected tissues. Along these lines *Hessov* et al. [6] point out that muscle fatigue and other early symptoms of Mg deficiency correlate positively with low concentrations of muscle Mg, not detectable at serum level. Several reports [18, 19] communicated that chronic Mg deficiency leads to a complex array of biochemical, electrophysiological and morphological abnormalities in skeletal muscle. Histological studies have reported a reduction in the number of mitochondria or mitochondrial swelling, and metabolic studies have revealed a partial uncoupling of oxidative phosphorylation. Cellular phosphagen levels appear to become rapidly depleted [20]. This could explain why, in our study, we have observed a certain fluctuation of serum and erythrocytic Mg within normal limits and would justify the increase observed on 9–D of convalescence.

To summarise, the level of subjective fatigue increases in the early postoperative period (9–D) and remains high 27 days after surgical intervention, both stages presenting a close correlation with other objective indices of muscular function. What is more, although serum Mg remained within normal physiological limits during convalescence they displayed sufficient modifications to justify their implication in the appearance of fatigue during the postoperative period.

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