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CLINICAL INVESTIGATIONS

A CLINICAL STUDY TO EVALUATE THE ROLE OF INTRAOPERATIVE MAGNESIUM SULPHATE FOR PROPHYLAXIS AGAINST ARRHYTHMIAS IN PATIENTS UNDERGOING ELECTIVE OPEN HEART SURGERY.

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Background:
Hypomagnesemia seems to be a frequent finding in patients subjected to cardiac surgery under cardiopulmonary bypass (CPB) due to multifactorial etiology. Hypomagnesemia may be one of the many contributory factors that predispose towards the development of postoperative arrhythmias. Prophylactic magnesium administration in the perioperative period may be beneficial in the control of supraventricular tachyarrhythmias and ventricular ectopics after cardiac surgery. Hence we evaluated the role of intraoperative magnesium sulfate for prophylaxis against arrhythmias in patients undergoing elective open heart surgery under cardiopulmonary bypass.

Methods:
Forty adult patients of either sex scheduled for elective cardiac surgery under cardiopulmonary bypass were included in the study. Patients were randomly allocated to two groups of 20 patients each. Group I (study group): 16 mmol L^{-1} of magnesium sulfate was added to each litre of cardioplegic solution. Group II (control group): cardioplegic solution without magnesium sulfate was used.

Results:
Serum magnesium levels were measured preoperatively, immediately after surgery and 24 hours after surgery. Incidence of hypomagnesmia and arrhythmias were recorded pre and post operatively.

Conclusion:
Addition of magnesium sulfate in a dose of 16 mmol L^{-1} to cardioplegic solution is safe although it does not prevent the fall in serum Mg^{2+} levels following CPB. The relative risk for both ventricular and supraventricular arrhythmias is reduced.

Magnesium is an important mineral in the maintenance of normal cellular and bodily functions.[1,2] It is an important regulator of multiple cardiovascular processes including myocardial conduction, myocardial contractility, transmembrane calcium flux, potassium transport, vascular smooth muscle tone, coronary vascular reactivity and nitric oxide synthesis.[2,3] Hypomagnesemia seems to be a frequent finding in patients undergoing

cardiac surgery under cardiopulmonary bypass due to multifactorial etiologies like pharmacological treatment with β blockers, digitalis or diuretics, exogenous or endogenous catecholamine stimulation and diet deficiencies.[4,5]

Aglio et al. reported hypomagnesemia in almost 70% of patients following the cessation of CPB.[6] The intraoperative decrease in serum magnesium is explained by dilution of extracellular volume by non magnesium containing fluids.[5] It is also possible that high flow perfusion may greatly increase urinary loss of magnesium especially when mannitol is added to the priming fluid.[4]

Magnesium is a mineral that is involved in transmembrane and intracellular modulation of specific ion channels and ion transport processes. Overt Mg deficiency (<1.8 mg/dl) has been associated with ventricular arrhythmias, and correcting plasma levels of magnesium is certainly warranted.[7] Arrhythmias are common after open heart surgery and may be related to hypomagnesemia due to CPB.[8] The other factors that may contribute to dysrhythmias include digitalis, hypokalemia, volume overload, hypovolemia, pH changes and post cardiotomy irritability.[6]

Magnesium suppresses arrhythmias by multiple mechanisms which include a direct myocardial membrane stabilising effect, a direct or indirect effect on cellular potassium and sodium concentration, antagonism of calcium entry into cell, prevention of coronary artery vasospasm, antagonism of catecholamine action and improvement of the myocardial oxygen supply and demand ratio.[9,10]

Prophylactic magnesium administration in the perioperative period may be beneficial in the control of supraventricular tachyarrhythmias and ventricular ectopics after cardiac surgery.[11, 12] Mg^{2+} can be supplemented using intravenous or intracoronary routes. Intravenous magnesium supplementation is effective and acutely increases intracellular magnesium levels.[13]

Authors have established the effect of i.v magnesium sulfate on the frequency of postoperative atrial fibrillation (AF) in patients undergoing coronary artery bypass grafting (CABG) and on the frequency of AF at hospital discharge. CABG patients who received intraoperative and postoperative i.v. magnesium sulfate had a significantly lower rate of AF compared with patients who did not receive the drug.[14, 15]

The aim of the present study was to evaluate the role of intraoperative magnesium sulfate for prophylaxis against arrhythmias in patients undergoing elective open heart surgery under cardiopulmonary bypass.

Materials & Methods

The study was approved by hospital ethical committee and informed consent from all the participants was obtained. Forty adult patients of either sex scheduled for elective cardiac surgery under cardiopulmonary bypass were included in the study. Patients with history of endocrine or metabolic disorders, poor or borderline renal function, preopertive heart block, severe bradycardia and poor ventricular function (ejection fraction <0.3) were excluded from the study. It was a prospective randomized study.

All the patients were examined one day prior to surgery. Indication for cardiac surgery was noted. Details regarding clinical history, general physical examination, and systemic examination were recorded. Investigations like haemoglobin (Hb), bleeding time (BT), clotting time (CT), complete urine examination, blood sugar, serum creatinine, blood urea, HIV, australia antigen, prothrombin time index (PTI), serum glutamic oxaloacetic transaminase (SGOT), serum glutamic pyruvic transaminase (SGPT) and serum bilirubin were carried out. Electrocardiogram (ECG), chest X-ray, pulmonary function tests and

echocardiography were also obtained. Any other specific investigations if needed were also carried out. Basal values of pulse rate, non invasive systolic and diastolic blood pressure were recorded.

All the patients were premedicated with injection morphine 0.1 mg kg^{-1} and promethazine 0.5 mg kg^{-1} intramuscularly one hour prior to surgery. After arrival in operation theatre, monitoring such as 5 lead ECG (lead II, V), invasive blood pressure, central venous pressure, pulse oximetry was started. All the patients were randomly allocated to two groups of 20 patients each.

Group I (study group): 16 mmol L^{-1} of magnesium sulfate was added to each litre of cardioplegic solution.

Group II (control group): cardioplegic solution without magnesium sulfate was used.

Induction of anaesthesia was done with intravenous midazolam (0.03 mg kg^{-1}), fentanyl (3µg kg^{-1}), sleep dose of thiopentone and vecuronium (0.1mg kg^{-1}). Patients were intubated with cuffed endotracheal tube of appropriate size and ventilated with a tidal volume sufficient to maintain a $PaCO_2$ between 35 and 40 mmHg. Anaesthesia was maintained with isoflurane, fentanyl and vecuronium bromide. After this, urinary bladder was catheterised. Temperature and transesophageal echocardiography (TEE) probes were placed in each patient.

Cardiopulmonary bypass was established with a disposable membrane oxygenator pump. Priming fluid for pump contained 1 litre of hydroxyethyl starch, 500ml of ringer's solution, 3 ml kg^{-1} mannitol, 50 ml sodabicarb and 2g methyl prednisolone. During operation, systemic core temperature was maintained between 28°C to 30°C. Pump flow rate was kept at 2.4 l/min/m^2 body surface area at 37°C. For every 4°C fall in temperature, pump flow rate was reduced by 25%.

After the ascending aorta was cross clamped, the cardioplegic solution was injected either into the aortic root or the coronary arteries at a dose of 20ml kg^{-1}. Standard cardioplegic solution consisted of 20mEq of potassium chloride, 50mEq of sodium bicarbonate and 8mg of dexamethasone per litre of ringer's solution. For study group I 16mmol L^{-1} of magnesium sulfate was added to cardioplegic solution. Cardioplegia was delivered after every 20 minutes or the return of electrical activity whichever was earlier. First dose was 10ml kg^{-1} and subsequent doses were 5ml kg^{-1}. Supplemental potassium was added to the pump if required to maintain a serum potassium level greater than 3.5 meq L^{-1}.

Samples for serum magnesium were taken preoperatively (T_1) before induction of anaesthesia, postoperatively (T_2) on arrival of patient in the intensive care unit and again after 24 hours (T_3). The samples were centrifuged and the serum collected was kept in freezer until analysis was performed. Serum magnesium levels were analysed using "atomic absorption spectrometer" which was standardised each time. The results were expressed in milligram per decilitre (mg dl^{-1}). Normal range for serum magnesium with this spectrometer is 1.8 to 2.6 mg dl^{-1}.

After surgery all patients were shifted to the intensive care unit and intraoperative monitoring was extended there. Postoperative hypertension was managed with intravenous nitroglycerine infusion. Vasopressor support in the form of dopamine and adrenaline infusion was used as per standard protocol. Postoperative mechanical ventilation was continued until the residual effect of anaesthesia waned off and the cardiovascular and respiratory systems were judged to be satisfactory and stable.

ECG (lead II, V) was monitored continuously for 24 hours. Whenever arrhythmia was recognised a printed report of the actual ECG was taken. A single patient can have multiple types of arrhythmias. Although all arrhythmic events were noted, occurrence of only first

episode of arrhythmia was taken into account to calculate the incidence. The arrhythmias requiring intervention were treated as per standard protocol in both the groups.

Adverse effects that could be related to magnesium were categorised as delayed extubation (>6 hours), sedation and confusion, hypotension (<30% of basal systolic blood pressure), increased postoperative bleeding (>500 ml), and increased energy requirement for defibrillation (10-20 joules direct current used more than once).

Statistical analysis

At the end of study the data was compiled. For analysis of age, weight, sex, bypass time and type of surgery, Fisher's exact test was used. For magnesium levels paired and unpaired t-test was used. Unpaired t-test was used for comparison between groups and paired t-test for comparison within groups. For arrhythmia analysis, differences in proportions were analysed using chi-square test. A p value of less than 0.05 was considered to be statistically significant.

Results

Mean age and weight of patients between study and control group was statistically comparable (Table 1). Distribution of type of surgery in two groups is shown in (Table 2) and was comparable statistically. Approximately 50% patients were of MVR in both groups and rest were either of AVR or DVR. Mean bypass time in study group was 89.15 and control group was 95.55 which was also comparable statistically (p >0.05) (Table-3).

Preoperative hypomagnesemia was seen in 13 patients (32.5%), 7 in study Group and 6 in control Group (Table 4). Preoperative serum magnesium levels in Group I (1.83±0.14 mg dl^{-1}) and Group II (1.8±0.128 mg dl^{-1}) were statistically comparable (p>.05) (Table-5). Following CPB, in the immediate postoperative period there was a significant fall in mean magnesium levels in both the groups as compared to preoperative values (p<0.001). This decrease in magnesium levels persisted till 24 hours in both Groups (p<0.001) (Table 5).

Table 1
Age and weight distribution between the two Groups

Groups	Age (Years) (Mean±SD)	Weight (Kg) (Mean±SD)
Study (Group I, n=20)	34.1±10.32	47.65±6.74
Control (Group II, n=20)	33.9±7.59	48.5±7.96
p value	>0.05	>0.05

Table-2
Surgical distribution of patients in both the groups

Groups	MVR	AVR	DVR
Study (Group I, n=20)	13	3	4
Control (Group II, n=20)	12	3	5
p value	>0.05	>0.05	>0.05

Table-3
Bypass time in both the groups (minutes)

Groups	Bypass time (Mean±SD)
Study (Group I, n=20)	89.15±30.60
Control (Group II, n=20)	95.55±32.59
p value	>0.05

Table-4
Incidence of hypomagnesemia (serum Mg^{2+} levels <1.8 mg dl^{-1}) at different times in two groups

Groups	Pre op (T_1)	Post op (T_2)	After 24 hours (T_3)
Study (Group I, n=20)	7	15	17
Control (Group II, n=20)	6	19	20
Total (n=40)	13	34	37

Table-5

Mean±SD values of S. Mg^{2+} levels at different times in two groups (mg dl^{-1})

Groups	Pre operative (T1)	Post operative (T2)	After 24 hours (T3)
Study Group I, (n=20)	1.83±0.14	1.71±0.121**	1.65±0.114**
Control (Group II, n=20)	1.8±0.128	1.49±0.146**	1.45±0.134**
p value	>0.05	<0.001	<0.001

(Within group p value ** <0.001)

Table-6

Incidence of postoperative arrhythmias vs. preoperative in two groups

Groups	Incidence of preoperative arrhythmias	Incidence of postoperative arrhythmias
Study Group I, (n=20)	4 (20%)	11 (55%)*
Control Group II, (n=20)	5 (25%)	16 (80%)**
p value	>0.05	>0.05

(Within group p value * <0.05, **<0.001)

Table-7

Distribution of postoperative arrhythmic events in the two groups

Group	PVC	V T	SVT	Atrial Flutter	AF
Study Group I, (n=20)	7	0	1	2	2
Control Group II (n=20)	12	1	2	2	5

(PVC = Premature ventricular contractions; VT = Ventricular tachycardia; SVT Supraventricular tachycardia, AF Atrial fibrillation)

Table-8

Arrhythmias and serum magnesium levels (mg dl^{-1})

Arrhythmias	Pre op (T_1) S. Mg^{2+} levels	Post op (T_2) S. Mg^{2+} levels	After 24 hours (T_3) S. Mg^{2+} levels
Yes (n=27)	1.908±. 137	1.57± 0.179	1.526± 0.185
No (n=13)	1.803±. 128	1.65±0. 156	1.566± 0.146
p value	p >0.05	p >0.05	p >0.05

The mean value for serum magnesium concentration after CPB in the study group was significantly higher than that in the control group (1.71±0.121 vs. 1.49±0.146 mg dl^{-1}, p<0.001) and remained significantly higher till 24 hours after surgery (1.65±0.114 vs. 1.45 ±0.134 mg dl^{-1}, p<0.001).

The incidence of preoperative arrhythmias in two groups was comparable statistically (p>0.05, Table 6). There was a significant increase in the incidence of arrhythmias postoperatively as compared to preoperative values in the study group (20% to 55%, p <0.05) and the control groups (25% to 80%, p<0.001) but the relative risk for the increase in the incidence of arrhythmias was less in the study group as compared to the control group (2.75 vs. 3.2). Distribution of postoperative arrhythmic events is shown in Table-7. Ventricular arrhythmic events occurred more frequently in group II than in Group I (12 vs. 7). Although this difference was not significant statistically (p >0.05), indicating that arrythmogenicity is not directly linked to serum magnesium levels, but relative risk of ventricular arrhythmias was less in Group I as compared to Group II (0.54). Mean values of serum magnesium in patients with or without arrhythmias are shown in Table 8 and were also comparable in two groups.

We observed delayed extubation in one patient in Group I. Increased energy for defibrillation was required in two patients, out of which one was in the control group.

Discussion

Magnesium (Mg^{2+}) is the fourth most plentiful cation in the body and second most plentiful intracellular cation after potassium.[16] Magnesium is widely advocated in the treatment and prophylaxis of arrhythmias particularly in acute myocardial infarction (MI)[17], after cardiopulmonary bypass[18] and in digitalis toxicity.[19]

The antiarrhythmic mechanisms of magnesium sulfate are not fully understood. However magnesium sulfate is known to decrease the resting membrane potential and decrease the tendency to abnormal impulse formation. These effects have been suggested to be primarily mediated by an increasing Mg^{2+} dependent sodium potassium ATPase activity. Augmentation of sodium potassium ATPase activity elevates the intracellular potassium concentration, thus increasing the membrane threshold potential.[20]

Hypomagnesemia has been reported to be a frequent finding in cardiac surgical patients. Scheinman et al found preoperative hypomagnesemia in 44% of cardiac surgery patients.[5] Aglio et al reported preoperative hypomagnesemia in 19.2% of patients posted for coronary artery revascularisation.[6] Parra et al found 26.6% of the cardiac surgical patients to be hypomagnesemic preoperatively.[21]

The etiology of preoperative hypomagnesemia in the cardiac patients is multifactorial and it may be because of frequent use of drugs that adversely affect magnesium balance e.g. digoxin and diuretics.[19,22] Another factor that contributes to preoperative hypomagnesemia is suboptimal nutritional support due to anxiety, depression or anorexia and nausea produced by many oral drugs they are taking.[4]

In our study, preoperative serum magnesium levels were comparable in both the groups. Following CPB there was significant fall in serum Mg^{2+} levels in both the groups and this fall persisted for 24 hours. However patients in the study group (Group I) had a significantly higher mean serum magnesium level postoperatively than patients in the control group (1.71±0.121 vs. 1.49±0.146 mg dl^{-1}, $p<0.001$). This higher mean serum magnesium level in group I persisted for 24 hours postoperatively (1.65±0.114 vs. 1.45±0.134 mg dl^{-1}, $p<0.001$).

Our results are similar to the study of Shakerinea et al who observed that patients in whom Mg^{2+} was supplemented in cardioplegic solutions had a significantly higher mean serum magnesium level postoperatively than patients in whom cardioplegic solution without magnesium was given (1.02±0.41 vs. 0.78±0.12mmol L^{-1}) but the decline in serum magnesium levels was comparable in both the groups.[23]

It has been postulated that hypomagnesemia may be one of the many contributory factors that predisposes towards the development of postoperative arrhythmias.[8] The intraoperative administration of magnesium may reduce the incidence of potentially serious arrhythmias following CPB.[11, 12] In our study incidence of preoperative arrhythmias was comparable in both the groups but ventricular arrhythmic events occurred more frequently in Group II than in group I (12 vs. 7). The relative risk for the increase in the incidence of arrhythmias was less in the study group as compared to the control group (2.75 vs. 3.2). Cook et al who studied administration of prophylactic intravenous magnesium sulphate in addition to oral β-blockade reported that it does not reduce the incidence of atrial arrhythmias after coronary artery or valvular heart surgery.[24] In a similar study conducted by Shakerinea et al observed that ventricular arrhythmias occur significantly more frequently in patients in whom cardioplegic solution was not supplemented with Mg^{2+}.[23]

In our observations we did not find any statistically significant correlation between postoperative mean serum Mg^{2+} levels and the incidence of cardiac arrhythmias. Mean

postoperative serum magnesium levels in patients who had arrhythmias were not statistically different from those who had no arrhythmias. Studies of Schienman et al and Parra et al also found no apparent relationship between postoperative levels of serum Mg^{2+} and the presence of cardiac arrhythmias.[21,25] This lack of correlation may be because plasma levels of Mg^{2+} represent only less than 1% of the total Mg^{2+} pool of the body and do not reflect intracellular concentration of this cation. This lends support to the notion that cellular magnesium determinations may provide a more accurate assessment of magnesium homeostasis than serum based determinations in diagnosing magnesium deficiency.[18]

Adverse effects that could be related to magnesium therapy include delayed extubation, sedation, hypotension, increased postoperative bleeding and increased energy requirement for defibrillation.[26,27,28] We observed delayed extubation in one patient in Group I. Increased energy for defibrillation was required in two patients, one was in the non magnesium group. Adverse effects related to magnesium intoxication usually appear at serum magnesium levels above 9 mg/dl[26] and none of the patients in our study had serum magnesium levels more than 3 mg dl^{-1}. There can be many other reasons for delayed extubation after open heart surgery e.g. residual effects of opioids, sedatives and muscle relaxants.

Thus we conclude that addition of magnesium sulphate to cardioplegic solution in a dose of 16mmol L^{-1} is safe. Although it does not prevent the fall in serum magnesium levels following cardiopulmonary bypass, the relative risk for both ventricular and supraventricular arrhythmias in the postoperative period are reduced.

References

1. Surawicz B. Is hypomagnesemia or magnesium deficiency arrhythmogenic. *JACC* 1989; **14**: 1093-6.
2. Salem M, Munoz R, Chernow B. Hypomagnesemia in critical illness: a common and clinically important problem. *Crit Care Clin 1991*; **7**: 225-52.
3. Pearson PJ, Evora PRB, Secombe JF, Schaff HY. Hypomagnesemia inhibits nitric oxide release from coronary endothelium: protective role of magnesium infusion after cardiac operations. *Ann Thorac Surg* 1998; **65**: 967-72.
4. Holden MP, Ionescu MI, Wooler GH. Magnesium in patients undergoing open heart surgery. *Thorax* 1972; **27**: 212-8.
5. Scheinman MM, Sullivan RW, Hyatt KH. Magnesium metabolism in patients undergoing cardiopulmonary bypass. *Circulation* 1969; **34**: 1235-41.
6. Aglio LS, Stanford GG, Maddi R, Boyd J. Hypomagnesemia is common following cardiac surgery. *J Cardiothorac Vasc Anesth* 1991; **5**: 201-8.
7. Vos MA. Enhanced efficacy with MgSO4 due to an additive, alternative, or dual mode of action? *Europace*, 2009; 11:**7**: 844 - 845.
8. Vyvyan HA, Mayne PN, Cutfield GR. Magnesium flux and cardiac surgery: A study of the relationship between magnesium exchange, serum magnesium levels and postoperative arrhythmias. *Anaesthesia* 1994; **49**: 245-9.
9. Altura BM, Turlapaty PD. Withdrawl of magnesium enhances coronary arterial spasm produced by vasoactive agents. *Br J Pharmacol* 1982; **77**: 649-59.
10. riedman HS, Nguyen TN, Makraoul AM. Effects of magnesium chloride on cardiovascular hemodynamics in neurally intact dog. *J Pharmacol Exp Ther* 1987; **243**: 126-30.
11. Harris MNE, Crowther A, Jupp RA. Magnesium and coronary revascularization. *Br J Anaesth* 1988; **60**: 779-83.
12. Iseri LT, Chung P, Tobias J. Magnesium therapy for intractable ventricular tachyarrhythmias in normomagnesemic patients. *West J Med* 1983; **138**: 823-8.
13. Haighey MC, Silver B, Tanglao E. Noninvasive measurement of tissue magnesium and correlation with cardiac levels. *Circulation* 1995; **92**: 2190-7.
14. **Brackbill ML and Moberg L.** Magnesium sulfate for prevention of postoperative atrial fibrillation in patients undergoing coronary artery bypass grafting. *Ann Thorac Surg* 2005; **79**:117-126.

15. **AerraV, Kuduvalli M, Moloto AN, Srinivasan AK, Grayson AD, Fabri BM** and **Oo AY.** Does prophylactic sotalol and magnesium decrease the incidence of atrial fibrillation following coronary artery bypass surgery: a propensity-matched analysis .*Journal of Cardiothoracic Surgery* 2006, **1:**6doi:10.1186/1749-8090-1-6.
16. Khilnani P. Electrolyte abnormalities in critically ill children. *Crit Care Med* 1992; **20**: 241-50.
17. Rasmussen HS, McNair P, Norregard P. Intravenous magnesium in acute myocardial infarction. *Lancet* 1986; **1**: 234-6.
18. England MR, Gordon G, Salem M, Chernow B. Magnesium administration and dysrythmias after cardiac surgery. *JAMA* 1992; **268**: 2395-402.
19. Cohn L, Kitzes R. Magnesium sulfate and digitalis toxic arrhythmias. *JAMA* 1983; **249**: 2808-10.
20. Knudson K, Abrahamsson J. Antiarrhythmic effects of magnesium sulphate. Report of three cases. *Acta Anaesthsiol Scand* 1995; **39**: 850-4.
21. Parra L, Fita G, Gomar C. Plasma magnesium in patients submitted to cardiac surgery and its influence on perioperative morbidity. *J Cardiovasc Surg* 2001; **42**: 37-42.
22. Lim P, Jacob E. Magnesium deficiency in patients on long term diuretic therapy for heart failure. *Br Med J* 1972; **3**: 620-2.
23. Shakerinia T, Ali IM, Sullivan JA. Magnesium in cardioplegia: Is it necessary? *Can J Surg* 1996; **39**: 397-400.
24. Cook RC, Humphries KH, Gin K, Janusz MT, Slavik RS, Bernstein V. Prophylactic Intravenous Magnesium Sulphate in Addition to Oral β-Blockade Does Not Prevent Atrial Arrhythmias After Coronary Artery or Valvular Heart Surgery. *Circulation* 2009; **120**:S163-S169.
25. Scheinman MM, Sullivan RW, Hutchinson JC, Hyatt KH. Clinical significance of changes in serum magnesium in patients undergoing cardiopulmonary bypass. *J Thorac Cardiovasc Surg* 1971; **61**: 135-40.
26. Grigore AM, Mathew JP. Cons: Magnesium should not be administered to all coronary artery bypass graft surgery patients undergoing cardiopulmonary bypass. *J Cardiothorac Vasc Anesth* 2000; **14**: 344-6.
27. Gries A, Bode C, Gross S, Peter K, Bohrer H, Martin E. The effect of intravenously administered magnesium on platelet function in patients after cardiac surgery. *Anesth Analg* 1999; **88**: 1213-9.
28. Hecker BR, Lake CL, kron IL, Metzes RM, Crosby IK, Nolan SP, et al. Influence of magnesium loss on human ventricular defibrillation after aortocoronary bypass surgery. *Am J Cardiol* 1985; **55**: 61-4.