



Obstetrical Accidents Involving Intravenous Magnesium Sulfate

Recommendations to Promote Patient Safety

ABSTRACT

Magnesium sulfate is commonly used in obstetrical practice both as seizure prophylaxis in women with preeclampsia, as well as to inhibit preterm labor contractions. However, despite (and perhaps because of) years of use and provider familiarity, the administration of magnesium sulfate occasionally results in accidental overdose and patient harm. Fortunately, in most instances when potentially fatal amounts of magnesium sulfate are given, the error is recognized before permanent adverse outcomes occur. Nevertheless, a significant and sometimes unappreciated risk of harm to mothers and babies continues to exist. Intravenous magnesium sulfate treatment has become routine practice in obstetrics, but this does not lessen the vigilance required for safe care for mothers and babies. Implementation of the recommendations provided in this article will promote patient safety and decrease the likelihood of an accidental overdose, as well as increase the chances of identifying an error before a significant adverse outcome occurs.

Key Words: Accidental overdose; Adverse outcomes; High-risk medications; Magnesium sulfate; Perinatal patient safety.

Because of widespread and extensive use of magnesium sulfate over many years in obstetrical practice for seizure prophylaxis and inhibition of preterm labor contractions, care providers are generally comfortable with its clinical indications, treatment protocols, and the signs and symptoms of magnesium toxicity. However, despite, and perhaps because of, its familiarity to providers, the administration of magnesium sulfate occasionally results in accidental overdose and patient harm. Fortunately, in most instances when potentially fatal amounts of magnesium sulfate are given, the error is recognized before permanent adverse outcomes occur. Nevertheless, a significant and sometimes unappreciated risk of harm to mothers and babies continues to exist.

The authors are involved in ongoing examinations of obstetrical accidents and perinatal patient safety. During our comprehensive investigations of obstetrical accidents, physicians and nurses from multiple institutions across the country have related many stories about intravenous (IV) infusions of magnesium sulfate that caused significant patient harm or potential harm (see Figure 1). Over the past several years we have accumulated a database of 52 cases involving accidental magnesium sulfate overdose. Unfortunately, these clinical scenarios are *not* uncommon, were known to have happened in at least two or more institutions, and *appear to involve similar themes and causative factors*. This article provides a representative summary of deidentified cases that resulted in various patient outcomes, and suggests changes in institutional practice to promote patient safety based on what has been learned from these accidents.

An important barrier to improving patient safety is lack of awareness of the extent and clinical context within which accidents occur in all healthcare settings and organizations. This lack of awareness exists because the vast majority of errors are not reported. One reason they are not reported is because personnel fear they will be punished (Kohn, Corrigan, & Donaldson, 1999). Studies of actual accidents and, more importantly, “near misses,” can contribute to a growing understanding of how to prevent, detect, and recover from accidents/errors before patient injury occurs (Simpson & Knox, 2003a). According to the recommendations from the recent report from the Institute of Medicine *To Err Is Human: Building a Safer Health System* (Kohn et al., 1999), healthcare organizations should implement methods to provide feedback and allow learning from errors. Clearly, having the opportunity to learn from a report/story of an accident is much preferable to being personally involved in an event that results in patient injury. Therefore, the purpose of this article is to share stories of obstetrical accidents involving IV magnesium sulfate, review suggested guidelines for safe practice when using magnesium sulfate, and assist other healthcare providers to avoid future similar adverse events.

An Overview of Magnesium Sulfate

The average adult human body contains approximately 0.33mg/kg (1.32 mmol/kg) or about 24 total grams of magnesium (Dacey, 2001). Magnesium is primarily an in-

tracellular cation with over 99% of nonskeletal stores found in the intracellular space. There is unequal distribution of magnesium throughout the body: The serum contains <1%, the skeleton contains between 50% and 60%, and the muscles contain 20% (Clark, Cotton, Hankins, & Phelan, 1997). Magnesium is intimately involved in maintaining ionic cellular balance, essential for virtually all hormonal reactions that occur in the body, a calcium channel blocker, and an obligate ion that is essential for the activation of over 300 enzymes (Dacey, 2001). These enzymes include those involved in glucose metabolism, fatty acid synthesis and breakdown, and DNA and protein metabolism (Blackburn, 2003). Magnesium sulfate is given intravenously to pregnant women who have preeclampsia or eclampsia and to women with preterm labor contractions. The therapeutic effects of magnesium sulfate are well known for these pregnancy conditions.

The normal laboratory values for serum magnesium sulfate range from 1.7 to 2.4 mg/dL. In the therapeutic range (4.8 to 9.6 mg/dL) magnesium sulfate slows neuromuscular conduction, depresses the vasomotor center, and depresses central nervous system irritability (Blackburn, 2003; Sibai, 2002). The side effects and toxicity of magnesium sulfate are dose dependent. During the initial IV bolus, many patients report flushing or “feeling hot” and blood pressure often drops slightly (Coustan & Mochizuki, 1998). Other common side effects include nausea and headaches (Hearne & Nagey, 2000). The variability of the baseline fetal heart rate pattern may decrease and there may be fewer accelerations of the fetal heart rate of 10 to 15 beats per minute during magnesium sulfate administration, although these changes are not usually clinically significant (Atkinson, Belfort, Saade, & Moise, 1994; Hiett, Devoe, Brown, & Watson, 1995; Wright, Ridgway, Wright, Covington, & Bobbitt, 1996). Magnesium sulfate circulates largely unbound to protein and is excreted in the urine (Sibai, 2002). Therefore, safe clinical practice requires an accurate record of intake and output when patients are receiving magnesium sulfate. In patients with normal renal function, the half-life for magnesium excretion is approximately 4 hours (Sibai). Significantly, women with preeclampsia may not have normal renal function.

Magnesium Sulfate Toxicity

Maternal respiratory rate, oxygen saturation, deep tendon reflexes (DTRs), and state of consciousness should be monitored closely to detect progressive magnesium toxicity (Table 1). Magnesium toxicity results in loss of DTRs and progressive muscle weakness, including the diaphragm and other respiratory muscles, leading to acute respiratory failure. In addition, an overdose of magnesium sulfate depresses the respiratory center in the brain further inhibiting respirations. Hypotension, complete heart block, and cardiac arrest can occur. One ampule of calcium gluconate 1 g (10 mL of a 10% solution) should be clearly labeled and kept at the bedside in a locked drug box. If respiratory depression occurs, 1 g calcium gluconate should be given IV over 3 minutes (Sibai, 2002). If respiratory arrest occurs, ventilation should be supported until the antidote takes effect

Figure 1. Cases of magnesium sulfate accidents.

Case	Description of Accident/Event/Patient Outcome
1	A woman in preterm labor was receiving IV magnesium sulfate. Despite treatment, precipitous labor and birth occurred. Oxytocin was ordered after delivery of the placenta. Instead of oxytocin, magnesium sulfate was infused at a rapid rate. The magnesium sulfate infusion had been discontinued and IV line removed from the pump but remained connected to the patient at the Y port. The patient was returned to her LDR room and vital signs reassessed approximately 1/2 hour later. The patient was found nonresponsive and not breathing. A code was initiated; resuscitation was difficult, defibrillation required 3 times and 9 minutes required to restore heart rate. Subsequently, it was learned that she received approximately 550 mL of the magnesium sulfate IV fluid (22 g of magnesium sulfate). Despite aggressive resuscitation, calcium chloride and intensive care, she did not regain consciousness and remains in a persistent vegetative state.
2	A woman with preeclampsia was receiving IV magnesium sulfate at 2 g per hour. Approximately 12 hours after birth, she was admitted to the postpartum unit where routine assessment occurred q1hour. The unit was busy. The woman wasn't seen for an hour and a half until the nurse entered the room and found the patient nonresponsive and not breathing. Resuscitation was initiated, but the patient never regained consciousness and remains in a persistent vegetative state. It was subsequently discovered that although the maintenance IV was not labeled, it contained 40 g of magnesium sulfate. Thus, the patient was inadvertently receiving two infusions of magnesium sulfate. The maintenance IV was supposed to be given via IV pump. Instead, the nurse used a roller-clamp device set at 125 mL per hour; however, the infusion had been running at 300 mL per hour. In the ensuing analysis, it was discovered that immediately before patient transfer, the bag of maintenance fluids was noted to be empty; the primary nurse asked someone else to find her a new bag of IV fluids. A liter bag of magnesium sulfate had been prepared for another patient in the recovery room, but the label not yet attached. Between the hurried activities of the unit, the distraction of handoff and lack of label, the bag of magnesium sulfate was hung instead of lactated ringer solution.
3	A woman with preeclampsia being transferred to a tertiary care center was receiving IV magnesium sulfate at 2 g per hour. Because the maternal transport team was not available, a critical care nurse was selected to accompany the patient. Illegibly written orders to continue the magnesium sulfate at 2 g per hour were interpreted by the nurse to be 7 g per hour, and the dosage was adjusted accordingly. The patient appeared stable, was noted to be sleeping during the last portion of the trip, and found to have respirations of 10 per minute on arrival. The error in order interpretation and dosage was discovered by nurses at the accepting institution. Calcium gluconate was administered and respiratory status improved quickly.
4	A woman with preeclampsia was receiving IV magnesium sulfate (normally, the unit protocol was 20 g of magnesium sulfate in 1 L of normal saline; infusion = 2 g/100 mL per hour). In order to restrict fluids, the physician gave a verbal order to mix 40 g in 1 L (infusion = 2 g/50 mL per hour). The nurse who took the order did not write the order in the medical record or label the IV bag as containing 40 g of magnesium sulfate. Report to the next nurse was abbreviated because another high-risk patient required an emergent cesarean birth. The oncoming nurse noticed that the magnesium sulfate was infusing at 50 mL per hour, assumed the previous nurse had mistakenly programmed the pump and, therefore, increased the rate to 100 mL per hour (4 g of magnesium sulfate per hour). Hourly assessments noted progressively decreasing respirations, deep tendon reflexes, and level of consciousness. A serum magnesium sulfate level was found to be 12 mg/dL. When the original nurse who took the verbal order returned to care for the patient after the emergency had resolved, the error was discovered. The magnesium sulfate was discontinued until the woman's symptoms of magnesium sulfate toxicity resolved.
5	A physician wanted a stat magnesium sulfate infusion (4 g loading dose, then 2 g per hour) for a woman with severe preeclampsia. He asked one of the nurses to proceed and was assured she would get to it as soon as possible. He then repeated the order to a second nurse who gave the bolus and programmed the pump (magnesium sulfate at 2 g per hour). Meanwhile, the first nurse mixed the bolus, proceeded to the patient's room, noticed the IV magnesium sulfate infusing at 2 g per hour, and assumed that the bolus had not yet been given. Not wanting to reprogram the pump, she gave the 4 g bolus over 20 minutes while remaining with the patient. Later, when documenting the administered bolus, it became apparent that a bolus had previously been given and charted by the other nurse. A magnesium sulfate level was found to be 9.6 mg/dL. The patient did not suffer any adverse effects.
6	A woman with preeclampsia was admitted for labor induction. IV magnesium sulfate was ordered (4 g loading dose, followed by 2 g per hour). The nurse added the magnesium sulfate to 1 L of normal saline from the floor stock of magnesium sulfate. The pump was programmed for the 4 g loading dose to be given over 30 minutes. Based on 40 g of magnesium sulfate in 1 L, she set the pump at 200 mL per hour (100 mL [4 g] over 30 minutes). The nurse remained at the bedside for the first 20 minutes but then was called away to see another patient. By the time she returned (25 minutes later), 150 mL of IV fluid had infused. The patient reported feeling very hot, nauseated, and having difficulty moving her extremities; respirations were shallow and deep tendon reflexes were absent. A magnesium sulfate level was drawn, the magnesium sulfate was discontinued and calcium gluconate ordered as the patient's respiratory status continued to deteriorate. The woman improved quickly. A magnesium sulfate level of 12.8 mg/dL was reported. The attending physician felt the woman's symptoms were in excess of those expected based on receiving 6 g of magnesium sulfate and ordered an evaluation of the fluid in the IV bag with magnesium sulfate. 80 g of magnesium sulfate were found in the liter of normal saline instead of the expected 40 g. The nurse who prepared the magnesium sulfate had misread the labels on the floor stock magnesium sulfate vials.

Figure 1. Cases of magnesium sulfate accidents. (cont'd)

Case	Description of Accident/Event/Patient Outcome
7	A woman with preterm labor had orders for a 6 g loading dose of magnesium sulfate to be followed with 3 g/hour. The mainline IV fluids of L/R were to run at 300 mL/hour. The nurse mixed 40 g of magnesium sulfate in 1 L of L/R and labeled the bag as such. The nurse gave the 6-g loading dose without an infusion device and then used a pump to administer the magnesium sulfate and mainline fluids. Over the course of the next 3 hours, the woman reported feeling flushed and nauseated. Deep tendon reflexes were not assessed. The respiratory rate decreased to 10. The woman eventually appeared to be sleeping deeply. During the initial onset of symptoms of magnesium toxicity, the nurse assured the woman and her family members that these symptoms were normal and to be expected when receiving magnesium sulfate IV. When the woman appeared to be sleeping, the nurse assumed she needed her rest after stress of being admitted in preterm labor. The patient's family members went to dinner and returned to find the woman not breathing. When called to the room, the nurse could not palpate a pulse. A code was initiated, but was unsuccessful. After the code, magnesium toxicity was suspected, and the IV fluids were sent for analysis. It was discovered that the bag of L/R labeled with magnesium sulfate did not contain magnesium sulfate. The unlabeled bag of L/R contained 40 g of magnesium sulfate. The labels on the bags had been mistakenly switched so that the nurse was infusing what she thought was the mainline fluids at 300 mL/hr. Instead the woman had been receiving 12 g of magnesium sulfate per hour for 3 hours.
8	A woman with preterm labor was admitted with orders for a 6 g loading dose of magnesium sulfate to be followed with 3 g per hour until uterine activity subsided, then 2 g per hour. A premixed bag with 40 g of magnesium sulfate was hung. The nurse set the pump to deliver the loading dose over 20 minutes at 450 mL/hour. She remained at the bedside and planned to decrease the rate after the bolus was infused. She did not set the pump to stop the infusion after the 6-g loading dose. Another patient called for the nurse. She forgot to return to the room to reset the pump. An hour later when she returned, she realized the magnesium sulfate was still infusing at the 450 mL per hour rate. The woman received 18 g of magnesium sulfate over the course of the hour. She was difficult to arouse and had a respiratory rate of 8. Calcium gluconate was given, along with an 800-mL bolus of lactated ringer solution IV. The woman's condition improved rapidly with these interventions. The magnesium sulfate level was 11.4 mg/dL.
9	A woman with twins was receiving IV magnesium sulfate for preterm labor. She had multiple medical problems, including a long history of kidney disease and a kidney transplant 2 years earlier. After initial stabilization in labor and delivery, she was transferred to the antepartum/postpartum unit with IV magnesium sulfate infusing (2.5 g per hour). Unit policy for stable patients receiving IV magnesium sulfate for preterm labor included hourly assessments for the first 4 hours, then assessments every 2 hours. Eight hours later, the patient was noted to have respirations of 8 per minute, absent deep tendon reflexes, and was difficult to arouse. Magnesium sulfate was discontinued and calcium gluconate administered. Respiratory status did not improve necessitating ICU transfer and ventilatory assistance for several hours. Contractions, spontaneous rupture of membranes, active labor, and precipitous birth of the twins occurred in the ICU. The neonatal resuscitation team responded quickly, and the babies eventually did well after 3 months of hospitalization. The woman recovered completely after 2 additional days in the ICU.
10	A woman was admitted to the emergency room with symptoms of preterm labor. The ER physician initially ordered magnesium sulfate at a rate of 2 g/hour for stabilization in preparation for transport to a tertiary care center. When he called the pharmacy to confirm the correct dose, the pharmacist recommended increasing the dose to 4 g per hour. The physician crossed out the 2 and inserted a 4 next to the 2 g/hour orders. The ER nurse interpreted the order to read 42 grams per hour. She added 40 g of magnesium sulfate to the premixed bag of normal saline with 40 g of magnesium sulfate and set the infusion to run at 42 g per hour. Although she was aware this was a large dose and large amount of IV fluids to be infusing per hour, she remembered that patients in preterm labor often respond favorably to IV fluid boluses. She assumed this dose of magnesium sulfate and IV fluid amount was part of the treatment plan. The woman was transferred to the tertiary care center. The error in dosage was discovered soon after admission when the woman had a respiratory arrest. Calcium gluconate was given during the code. The woman recovered after 24 hours in the ICU. A magnesium level drawn 30 minutes after the code was 16.8 mg/dL.
11	Four hours postpartum a woman with "mild" preeclampsia was receiving IV magnesium sulfate (2 g per hour). During labor and birth, the woman was normotensive with no other obvious signs of preeclampsia. The nurses questioned the need for magnesium sulfate, assessed the patient's mobility the first time out of bed as adequate, told her to assist herself to the bathroom, and indicated she could push the pump as she moved. No activity orders were written, and a unit policy about activity levels for women receiving magnesium sulfate did not exist. In assisting herself to the bathroom, the woman fainted, fell, and fractured her skull and wrist. She was immediately found by a nurse who heard the pump and patient fall, required an additional 6-day inpatient stay, and eventually made a full recovery.
12	A woman 4 days postpartum after an apparently healthy vaginal birth presented to the emergency room in a small rural hospital with complaints of severe headache, blurred vision, and epigastric pain. Her BP was 168/110 and 4+ pitting edema was noted in her legs and ankles. The ER staff physician ordered magnesium sulfate to be given as a 2 g loading dose to follow at 1 g per hour. A premixed bag with 40 g of magnesium sulfate was sent by the pharmacy. Together, the ER physician and nurse calculated the infusion rate the pump should be programmed to deliver 1 g per hour. They jointly decided that 250 mL was the correct infusion rate. Two hours after the infusion was started, the woman was transferred to the postpartum unit. Report was abbreviated because the ER was busy. The admitting nurse noted the 250-mL rate and assumed that the magnesium sulfate must have been discontinued and that this rate was the mainline bag. She made this assumption because she knew 250 mL/hour was too high for magnesium sulfate. She did not confirm the rate and contents of each line. Approximately 30 minutes later, the patient's husband called to say his wife was feeling weak and unable to move. The error was noted when the nurse reassessed the patient. The patient had received 25 g of magnesium sulfate over the 2.5 hours of infusion. Calcium gluconate was given, after which the patient rapidly improved.

(Sibai). IV fluids administered at a rapid infusion rate can assist excretion of magnesium sulfate (Coustan & Mochizuki, 1998). While significantly high values (30-35 mg/dL) are frequently reported as being necessary to cause cardiac arrest, it is important to remember that an untreated respiratory arrest will lead to cardiac arrest as the cardiac muscle becomes hypoxic and ischemic (Clark et al., 1997). Thus, cardiac arrest can occur at magnesium levels consistent with respiratory failure if the respiratory failure is not identified and treated immediately. Magnesium levels causing cardiotoxicity are not required to cause cardiac arrest.

Maternal-Fetal Assessment Recommendations

Maternal and fetal status should be assessed and documented before the medication is administered. Assessments include maternal vital signs, oxygen saturation, level of consciousness, characteristics of the fetal heart rate, and uterine activity. During administration of the initial 4 g to 6 g bolus over 20 to 30 minutes, the nurse should remain at the bedside continuously assessing maternal-fetal status. The American Academy of Pediatrics and the American College of Obstetricians (2002) recommend one-to-one nursing care during labor for women with medical or obstetric complications. As a suggested protocol, all parameters, including how the woman is tolerating magnesium sulfate, should be documented in the medical record every 15 minutes during the first hour, every 30 minutes during the second hour, and at least hourly while the maintenance dose is infusing. These hourly assessments should continue while the medication is administered even for those patients who are considered to be stable. Signs and symptoms of magnesium toxicity should be evaluated and ruled out during each assessment. DTRs should be assessed prior to administration of the medication, at least every 2 hours thereafter, and as needed based on maternal signs and symptoms. Oxygen saturation should be assessed once per hour. Breath sounds should be auscultated before the initial administration of magnesium sulfate, then every 2 hours thereafter. Women with evolving magnesium toxicity may have a change in their respiratory pattern (e.g., prolonged expirations) before the respiratory rate itself begins to decrease.

Pregnant women receiving magnesium sulfate should be assisted to a comfortable lateral position that will promote adequate placental perfusion. Blood pressure (BP) should be assessed with an appropriate size cuff in the same arm and with the woman in the same position as previous BP measurements. Ideally, BP is assessed with the woman in a semisitting position with the arm at the level of the heart, but the key issue is maintaining the same clinical conditions for each BP assessment so that trends can accurately be identified. While automatic BP devices offer convenience and ease of use, a mercury BP cuff and stethoscope is the more accurate method of assessing BP in pregnant and laboring women. Automatic BP devices tend to over-

Table 1.
Magnesium Levels With Corresponding Clinical Symptoms

Symptoms	Milligrams per deciliter
Normal adult values	1.7-2.4
Loss of patellar reflexes	8-12
Feelings of warmth, flushing	9-12
Somnolence	10-12
Respiratory difficulty/depression	12-16
Muscular paralysis	15-17
Altered cardiac conduction	> 18
Cardiac arrest	30-35

Adapted from Sibai, 2002.

estimate systolic BP by 4 to 6 mmHg and underestimate diastolic BP by 10 mmHg when used with pregnant women (Brown et al., 1994; Franx et al., 1994). In addition, pregnant women often report significant discomfort from automatic BP devices, especially if these devices are left in place for long periods.

When the patient is receiving magnesium sulfate because of preeclampsia, signs and symptoms of worsening disease such as visual disturbances, headache, epigastric pain, clonus, and decreased urine output should be evaluated and either reported or ruled out during each assessment. For women with preeclampsia an indwelling urinary catheter will assist in determining accurate urine output if a question of adequacy exists.

If magnesium sulfate is being used for preterm labor prophylaxis, it is important to note any changes in uterine activity. Often women in preterm labor receive magnesium sulfate after significant amounts of IV fluids have been infused in an effort to inhibit contractions. This practice increases the risk for pulmonary edema. Therefore, careful assessment of respiratory status including rate and clarity of breath sounds is required as well as accurate recording of fluid intake and output. Signs and symptoms of pulmonary edema include shortness of breath, chest tightening or discomfort, cough, oxygen saturation below 95%, increased respiratory and heart rates, and adventitious breath sounds. Changes in behavior such as apprehension, anxiety, or restlessness may be additional signs of pulmonary edema or hypoxemia and should be closely monitored, documented, and reported.

The physician should be notified if a woman experiences any of the following symptoms:

- Significant changes in BP from baseline values.
- Double (or blurring of) vision.
- Tachycardia or bradycardia.
- Respiratory rate <14 or >24.
- Oxygen saturation <95%.
- Changes in breath sounds suggestive of pulmonary edema.
- Changes in level of consciousness or neurologic status.

- Absent DTRs.
- Urinary output <30 mL/hr.
- Nonreassuring fetal heart rate pattern.

Magnesium Sulfate Laboratory Data

Institutional protocols differ widely concerning the need for or frequency of obtaining laboratory determinations of serum magnesium levels. In theory, a thorough maternal assessment including vital signs, level of consciousness, muscle tone, and DTRs should be sufficient to determine if magnesium levels are excessive. Therapeutic levels also can be evaluated by whether the intended effect (inhibition of preterm uterine contractions, diminished hyperreflexia, and/or prevention of eclamptic seizures) has occurred. If a question exists concerning therapeutic or toxic levels based on the patient's clinical condition or symptoms, a laboratory evaluation of serum magnesium levels can be useful in clinical management. It is important to remember that therapeutic and toxic serum levels of magnesium sulfate differ within and between individual patients. This suggests that, ultimately, determining toxicity in a given patient should be more of a clinical assessment than a laboratory evaluation. One patient may require a level of 10 mg/dL to inhibit contractions while for another patient this level may cause respiratory depression. Renal function is a significant determinant of each woman's tolerance of the drug.

Deep Tendon Reflexes

Assessment of DTRs provides valuable information about neuromuscular status. Magnesium sulfate slows neuromuscular conduction and depresses central nervous system irritability. One sign of magnesium toxicity is diminished to absent DTRs. To elicit a DTR, strike the tendon of the partially stretched muscle briskly using a quick wrist movement. The flat or the pointed area of the hammer can be used and the strike should be directly on the tendon. The speed and amplitude of the reflex response is noted. Reflexes are usually graded on a 0 to 4 scale:

- 4 = very brisk (often associated with clonus)
- 3 = brisker than average (can indicate clonus)
- 2 = average/normal
- 1 = diminished (often abnormal)
- 0 = absent (abnormal)

It is generally assumed that a patient with normal (2) reflexes has a serum level of magnesium sulfate below 8 to 12 mg/dL, because reflexes are often absent at these levels or higher (Elliott, 1997). However, it is important to remember that each patient may have a different response to various serum concentrations.

Patient Education

A woman receiving IV magnesium sulfate is likely to have either preeclampsia or preterm labor contractions. These clinical conditions can cause great concern for both the woman and her baby. Therefore, it is important to fully explain why the drug is needed, what types of symptoms may be experienced during the initial bolus and maintenance in-

fusion, as well as assure the patient that her nurse will remain at her side for the first hour and as needed. The type and frequency of maternal-fetal assessments should be discussed. This information can provide reassurance that she is being well cared for, what to expect as things progress, and decrease anxiety if side effects occur.

Conditions That May Make Magnesium Sulfate Accidents More Likely (Based on Case Studies)

An evaluation of the cases in Figure 1 allows identification of common themes and precursors to the accident. Consistent with what is known about how errors occur (Reason, 2001), each of the accidents involves more than one condition that made the error more likely and more than one person involved in the chain of events. In several cases, there were existing safety procedures that, if followed, could have prevented the accident; while in others, safety procedures were implemented after the accident occurred.

- Transfer of patient (cases 1, 2, 3, 9, 10).
- Change of shift/change of nurse care provider/handoffs (cases 1, 2, 3, 4, 5, 9, 10, 12).
- High census, inadequate staffing to meet the needs of the unit at the time, unavailability of nurses with specialty skills (cases 2, 3, 4, 5, 6).
- Care providers unfamiliar with pregnant women and the use of magnesium sulfate during pregnancy (cases 3, 10, 12).
- Chaotic environment; multiple or changing nursing assignments (cases 1, 2, 3, 4, 5, 6).
- Different protocols, policies, procedures from one unit to another (cases 2, 9).
- Assumptions and miscommunication between nurses and/or physicians (cases 2, 3, 4, 5).
- Multiple pump settings (cases 3, 4, 8).
- Nurses mixing their own magnesium IV solutions rather than using premixed solutions or pharmacy prepared solutions (cases 2, 4, 5, 6, 7, 10).
- Inadequate labeling of IV fluids (cases 2, 4).
- Precipitous preterm birth (cases 1, 9).
- Not removing the magnesium sulfate from the Y-port after the order to discontinue the infusion or when it is obvious that it is no longer needed (preterm birth for woman without preeclampsia) (case 1).
- Line removed from the pump, free flow IV (case 1).
- Assuming women on magnesium sulfate are "stable" (cases 2, 7, 9, 11).

One potentially contributing factor is the recent trend to transfer women receiving IV magnesium sulfate from labor and delivery units where there is intensive nursing care to antepartum or postpartum units where there are fewer nurses for each patient. Often unit protocols for women receiving magnesium sulfate who are considered to be stable include assessment of maternal-fetal status hourly or every 2 hours. It is likely during times of increased census and acu-

ity that these patients are not seen by a nurse except during the prescribed maternal-fetal assessments, or in some situations, less frequently. Often when women receiving magnesium sulfate are considered stable, the assessments are limited to maternal vital signs rather than the comprehensive assessment of all clinical parameters during the initial phase of treatment. Designating a patient as *stable* may contribute to an illusion that the woman is no longer at risk for magnesium toxicity and no longer requires careful close assessment on a frequent basis.

In our database of 52 magnesium sulfate accidents, there were 7 women who died or who remain in a persistent vegetative state. In these cases where there was a lethal overdose of magnesium sulfate, common factors were identified, including use of 1000 mL IV bags with 40 g of magnesium sulfate (rather than 500 mL with 20 g), temporary removal of the IV line from the IV pump, a busy unit and/or understaffing, transfer to a less intensive level of care (e.g., the woman was considered "stable" and transferred to the antepartum or postpartum unit), and an unwitnessed respiratory arrest.

Other trends we have noted in magnesium sulfate accidents include the use of the liter bag for administration of the bolus by programming the pump to infuse the bolus at a rapid rate and then reprogramming the pump to a slower rate for the maintenance dose instead of using separate IV bags for the bolus and for the maintenance fluids. In some units, nurses continue to mix magnesium sulfate for the initial bolus and maintenance dose instead of using premixed IV fluids for both. Not all units have converted to the use of 500 mL premixed IV bags instead of the liter premixed IV bag for the maintenance dose. These trends were themes identified as contributing factors in the cases presented.

Designing Systems for Safety

When patient injury or harm occurs, causation is usually assigned to professionals providing direct patient care (i.e., providers at the "sharp end" of the system where errors become visible only because patient morbidity or mortality has occurred). Preventing errors by "telling people to be more careful" or "sending them for remediation" (i.e., "blaming and training") has been the approach used most often to prevent patient injury. However, prevention of harm requires recognition that multiple vulnerabilities inherent in imperfect systems rather than individuals are the cause of medical (obstetrical) accidents. It requires an average of 4.5 latent system errors occurring coincidentally to produce each medical accident (Reason, 1997). It is virtually impossible for one person or one error to be solely responsible when a mistake leads to patient injury. The critical issue is to have systems in place to catch errors before they result in adverse outcomes (Simpson & Knox, 2003b). When this view is adopted, it follows that sharp end professionals do not cause patient harm. Instead, it becomes clear that nurses in their

day-to-day work create safety through numerous "good catches" or "near misses" that are routinely produced by the imperfect systems of which they are a part.

Prevention of harm occurs when system gaps and vulnerabilities as well as the organizational context in which human error occurs have been systematically recognized and minimized (Reason, 1997). Errors may occur because of interruptions, fatigue, time pressure, anger, anxiety, fear, or boredom. Changing the conditions of work can decrease the likelihood of errors. *Systems designed to anticipate, recognize, intercept and mitigate the potential effects of human error are safer than those attempting to prevent error* (Reason, 2001). For example, prevention of error should

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not rely on known-to-fail aspects of human cognition such as short-term memory and mathematical calculations. Safe design avoids reliance on memory, substituting protocols and checklists instead. Simplifying key processes, standardization, constraints, and forced functions all reduce reliance on memory and mathematical skills and, thus, are the hallmark of well-designed safe systems (Kohn et al., 1999).

In addition to designing systems that bypass human memory as a strategy of error prevention, it is important to design systems capable of mitigation and recovery when error does occur. Examples of procedures to mitigate injury (Kohn et al., 1999) are as follows:

- Keep antidotes for high-risk medications up-to-date and easily accessible.
- Have procedures in place for responding quickly to adverse events, such that these processes are standardized across units and personnel are provided with drills to familiarize them with the procedures and the actions each person should take.
- Use equipment that defaults to the least harmful mode in a crisis.
- Provide simulation training with all members of the healthcare team participating together.

Magnesium Sulfate as a High-Risk Medication

Patient safety from the patients' perspective is freedom from accidental injury (Kohn et al., 1999). Error occurs frequently in the delivery of high-risk intensive care such as obstetrics. Medication errors are the largest single category of errors and

accidents that occur in healthcare (Combes, 2003). When an error occurs while magnesium sulfate is being administered, the difference between patient survival (near miss, good catch) and an adverse outcome is the ability to recognize, catch, and mitigate potential consequences of the error in a timely manner (Reason, 2001). As the cited cases demonstrate, the potential for patient injury secondary to the use of magnesium sulfate is very real. Therefore, the risks of magnesium sulfate toxicity and/or overdose should be thoroughly known to all providers. In addition, each perinatal unit should have a well-designed system incorporating recognized safety standards and principles for magnesium sulfate administration.

The IOM (Kohn et al., 1999) has identified magnesium sulfate as a high-risk medication and has provided recommendations that apply to all high-risk medications:

- Implement standardized processes for medication dosages, dose timing, and dose scales.
- Have the central pharmacy supply high-risk IV medications.
- Use special procedures and written protocols for the use of high-risk medications; both to alert personnel to be especially careful and to ensure that dosing is appropriate (special protocols and processes should be used for these high-alert drugs). Such protocols may include written and computerized guidelines, checklists, preprinted orders, double-checks, special packaging, and labeling.
- Use prepackaged premixed medications (errors in drugs mixed by nurses = 20%; pharmacists = 9%; manufacturers = 0.03%).
- Standardize prescription writing and prescribing rules.
- Limit the number of different kinds of delivery equipment (infusion pumps).
- Implement physician order entry.
- Use pharmaceutical software.
- Implement unit dosing.
- Do not store concentrated solutions of hazardous medications on patient care units.
- Ensure the availability of pharmaceutical decision support.
- Include a pharmacist in patient rounds.
- Make relevant patient information available at the point of care.
- Improve patients' knowledge of their treatment.

The 2003 National Patient Safety Goals from the Joint Commission on Accreditation of Healthcare Organizations (JCAHO, 2003) include recommendations that apply to the administration of magnesium sulfate. Specifically, JCAHO recommends implementing processes to improve communication among providers, to improve safety when using high-risk medications, and to improve safety of use of infusion pumps.

Specific Recommendations to Promote Patient Safety for Women Receiving Magnesium Sulfate

In addition to the general IOM (Kohn, 1999) recommendations for high-risk medications outlined previously, we

propose the following recommendations specific to magnesium sulfate:

- All nurses and physicians as a team should be taught and have an understanding of the signs and symptoms of therapeutic levels of magnesium sulfate and levels suggesting toxicity.
- Perinatal leaders at each institution should decide what laboratory values will be used for reporting results, professional communication, and medical record documentation of serum magnesium determinations. For example, magnesium levels are alternatively reported in the literature and by hospital laboratories as milligrams per deciliter (mg/dL), milliequivalents per liter (mEq/L) and millimoles per liter (mmol/L). When reviewing laboratory values to determine therapeutic levels it is important to realize that these numbers are not the same. Each of the values is different based on the measurement data being reported.
- Unit policies, protocols, and standing orders should be consistent with what is taught to all healthcare providers and reported by the hospital laboratory. A unit protocol with standardized, standing orders should be developed for magnesium sulfate administration including:
 - the initial bolus and the maintenance dose to be administered; *individual orders from each physician for magnesium sulfate administration should be avoided*;
 - how the pump will be programmed;
 - the maintenance IV solutions that will be used;
 - the frequency that the mother and fetus will be evaluated.
- Administer IV magnesium sulfate (including the initial bolus) only through a controlled infusion device with free-flow protection.
- Use universal standardized dose prepackaged magnesium sulfate for both the bolus and maintenance fluids.
- Avoid using "double and triple concentrations" for fluid restriction.
- Clearly label IV bags with easy-to-read large print and color-coded labels.
- Use 500 mL (20g) magnesium sulfate bags versus 1000 mL bags for the maintenance fluids.
- Use a 100 mL (4 g) or 150 mL (6 g) IVPB solution for the initial bolus instead of bolusing from the main bag with a rate change on the pump.
- Use color-coded tags on the lines as they go into the pumps and into the IV ports.
- Provide 1:1 nursing care during the first hour of magnesium sulfate administration.
- Provide 1:1 nursing care for women in labor receiving magnesium sulfate.
- Provide 1:2-3 nursing care during the maintenance dose in a clinical setting where the patient is close to the nurses' station rather than on the general antepartum or postpartum nursing unit where nurse to patient ratios are less.
- Consider that a woman receiving magnesium sulfate

remains high-risk even when symptoms of preeclampsia or preterm labor are stable.

- Have a second nurse check the initial magnesium sulfate IV bag and pump settings (and every magnesium sulfate IV bag that is added and each subsequent rate change).
- When care is transferred to another nurse, have both nurses together at the bedside review the pump settings for both the magnesium sulfate and the mainline IV fluids and review the written physician orders for magnesium sulfate infusion.
- Once the medication therapy is completed (i.e., preterm birth after failed IV magnesium sulfate prophylaxis; no longer needed 24 hours postpartum as seizure prophylaxis for women with preeclampsia), completely discontinue the medication by removing the line from the IV port to prevent accidental infusion and potential magnesium sulfate overdose.
- Implement periodic magnesium sulfate overdose drills with airway management and calcium administration with physician and nurse team members participating together.
- Maintain calcium antidote in the patients' room in a locked medication kit.
- Do not abbreviate magnesium sulfate as $MgSO_4$ anywhere in the medical record, including physician orders and ongoing documentation of patient status. Magnesium sulfate must be spelled out completely at all times.

Conclusion

IV magnesium sulfate treatment has become routine practice in obstetrics, but vigilance in its use is required for safe care for mothers and babies. Implementing the recommendations provided in this article will promote patient safety and decrease the likelihood of an accidental overdose as well as increase the chances that an error is identified before a significant adverse outcome occurs. ✚

Kathleen Rice Simpson is a Perinatal Clinical Nurse Specialist, St. John's Mercy Medical Center, St. Louis, MO. Dr. Simpson can be reached via e-mail at KRSimpson@prodigy.net.

G. Eric Knox is a Professor, Department of Obstetrics and Gynecology, University of Minnesota, Minneapolis, MN.

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Obstetrical Accidents Involving Intravenous Magnesium Sulfate: Recommendations to Promote Patient Safety



Instructions:

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- Take the test, recording your answers in the test answers section (Section B) of the CE enrollment form. Each question has only one correct answer.
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CE TEST QUESTIONS

General Purpose: To offer registered professional nurses an opportunity to review a representative summary of obstetrical accidents involving IV magnesium sulfate and provide guidelines for safe practice when using magnesium sulfate.

Learning Objectives

After reading this article and taking this test, you will be able to:

1. Discuss the role of magnesium as well as the actions and effects of magnesium sulfate.
 2. Outline the recommended procedures for administering IV magnesium sulfate for pregnancy complications.
 3. Make at least three recommendations for reducing magnesium sulfate accidents in obstetric nursing practice.
1. Fifty to sixty percent of the body's magnesium is
 - a. serum.
 - b. bone.
 - c. muscle.
 2. Magnesium sulfate is especially useful for treating some pregnancy complications because it
 - a. slows neuromuscular conduction.
 - b. deactivates enzymes essential for protein synthesis.
 - c. interferes with the body's hormonal activities.
 3. The most common side effect of IV magnesium sulfate administration is
 - a. diarrhea.
 - b. flushing.
 - c. insomnia.
 4. A change in the fetal heart rate pattern often noted during magnesium sulfate administration is
 - a. a decrease in variability.
 - b. an increase in the baseline.
 - c. an increase in the number of accelerations.

5. Magnesium sulfate toxicity can be reversed with IV
 - a. sodium bicarbonate.
 - b. calcium channel blockers.
 - c. calcium gluconate.
6. Respiratory depression is a serious concern when serum magnesium levels reach
 - a. 8 mg/dL.
 - b. 10 mg/dL.
 - c. 12 mg/dL.
7. Initial bolus administration of IV magnesium sulfate administration is
 - a. 2 to 4 grams over 5 to 10 minutes.
 - b. 4 to 6 grams over 20 to 30 minutes.
 - c. 6 to 8 grams over 20 to 30 minutes.
8. After an IV infusion of magnesium sulfate is started, deep tendon reflexes should be assessed at least every
 - a. 15 minutes.
 - b. hour.
 - c. 2 hours.
9. During an IV infusion of magnesium sulfate, the patient should be placed in a
 - a. lateral position.
 - b. semi-Fowler's position.
 - c. Trendelenburg position.
10. When used to monitor blood pressure in pregnant women receiving magnesium sulfate, automatic blood pressure devices tend to underestimate
 - a. systolic blood pressure.
 - b. diastolic blood pressure.
 - c. both systolic and diastolic blood pressure.

11. Of the following, the most significant determinant of how a particular patient tolerates magnesium sulfate is
 - a. renal function.
 - b. serum magnesium level.
 - c. presence of nausea.
12. A deep tendon reflex of 4+ in a woman receiving magnesium sulfate is an indication of
 - a. normal serum magnesium levels.
 - b. magnesium toxicity.
 - c. clonus.
13. Based on the case studies the authors summarized, which is the most common cause in magnesium sulfate accidents?
 - a. change of shift/nursing care provider
 - b. inadequate staffing
 - c. miscommunication between nurses and/or physicians
14. For reducing harm, the safest system design is one that
 - a. prevents errors.
 - b. finds the cause of errors.
 - c. intercepts errors.
15. Which of the following is recommended for promoting patient safety in women receiving magnesium sulfate?
 - a. having individual orders from each physician for magnesium sulfate administration
 - b. administering IV magnesium sulfate only via a controlled infusion device with free-flow protection
 - c. using double concentrations of magnesium sulfate for patients on fluid restrictions

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MCN, The American Journal of Maternal Child Nursing, May/June 2004:

Obstetrical Accidents Involving Intravenous Magnesium Sulfate:

Recommendations to Promote Patient Safety

A

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4. ☐ ☐ ☐

A B C

5. ☐ ☐ ☐

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7. ☐ ☐ ☐

8. ☐ ☐ ☐

A B C

9. ☐ ☐ ☐

10. ☐ ☐ ☐

11. ☐ ☐ ☐

12. ☐ ☐ ☐

A B C

13. ☐ ☐ ☐

14. ☐ ☐ ☐

15. ☐ ☐ ☐

C

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A B
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