normal volunteers. Subjects deliberately hyperventilated to an average end-tidal CO_2 concentration of 21.6 (SD, 3.2) mm Hg and then continued to hyperventilate into Kraft brown paper bags containing the calibrated sensors for a Hewlett-Packard 47210A capnograph and a Teledyne TED 60J digital oxygen monitor. Fourteen men and six women, average age of 36 years (SD, 6.1) were tested. Results, reported as millimeters of mercury, were identical for 2.25-L and 3.0-L paper bags and are thus combined. After 30 seconds of rebreathing, mean change in O_2 from room air was -15.9 (SD, 4.6) and mean CO_2 was 38.7 (SD, 6.2); at 60 seconds, -20.5 (6.0) and 40.2 (6.4); at 90 seconds, -22 (6.8) and 40.5 (6.4); at 120 seconds, -23.6 (6.8) and 40.7 (6.5); at 150 seconds, -25.1 (1.2) and 41 (7.3); and at 180 seconds, -26.6 (8.4) and 41.3 (7.5). A few subjects achieved CO_2 levels as high as 50, but many never reached 40. The mean maximal drop in O_2 was 26 (8.8); seven subjects had drops in oxygen of 26 mm Hg at three minutes, four had drops of 34 mm Hg, and one had a drop of 42 mm Hg. Three subjects rebreathed into an 18-L plastic bag filled with 100% O_2, but although CO_2 rapidly exceeded 40, O_2 levels reached 21% within two to four minutes and continued to decline to less than 10% at 15 minutes. Bag rebreathing does not consistently elevate CO_2 levels but it does decrease FiO_2 sufficiently to endanger hypoxic patients. Additionally, hypoxic respiratory drive is decreased by hypocapnia. Paper bag rebreathing should never be used unless myocardial ischemia can be ruled out and oxygenation has been directly measured by arterial blood gases or pulse oximetry. Because this cannot be achieved outside the hospital, its use by prehospital personnel should be abandoned, and in-hospital use probably should be greatly diminished.

144 Inhaled Sodium Bicarbonate Therapy for Chlorine Inhalation Injuries

CD Chisholm, EM Singletary, CV Okerberg, PC Langlinais/ Department of Emergency Medicine, The Joint Military Medical Command - San Antonio, Texas; The Institute for Surgical Research, Fort Sam Houston, Texas

Chlorine gas may cause inhalation injuries through exposures from industrial sources, home swimming pools, or admixtures of bleach and acidic cleaning solutions. Victims may rapidly present to the emergency department with dyspnea, chest pain, nonproductive cough, bronchospasm, tachypnea, and even pulmonary edema. Until recently, the Poisindex® recommended 5% nebulized $NaHCO_3$ as a treatment modality based on anecdotal reports, although the most recent edition states that "it cannot be routinely recommended." Our study was designed to examine the role of nebulized $NaHCO_3$ in the treatment of chlorine gas inhalation injury using a sheep model. Twenty-one sheep had internal jugular and carotid artery catheters placed by direct visualization. After being anesthetized with pentobarbital and succinylcholine, each sheep was endotracheally intubated and exposed to chlorine gas (500 ppm) for four minutes by a closed system. The animals then were placed on a Bird Mark 7 ventilator on room air. At 30 minutes after exposure, the animals were divided into two groups to receive a five-minute nebulized treatment (8 mL) of normal saline (Group A, ten) or 4% $NaHCO_3$ (Group B, 11). Arterial blood gases were sampled serially at five, 15, 30, 60, and 90 minutes and 24 hours after treatment. The animals then were euthanized and the organs taken for gross and microscopic examination. One-way ANOVA revealed no differences over time within groups with the exception of the GRA pO_2 ($f = 6.57$). t test for unequal groups revealed differences between groups with higher pCO_2 ($P < .001$) and lower pO_2 ($P < .05$) values for the control group. There was no difference in mortality rates before 24 hours for either group (three) or in microscopic pathology in blinded comparisons. The use of a single inhalation treatment of bicarbonate does not appear to worsen arterial blood gases or alter pathology in this sheep model and may actually improve arterial blood gas values.

145 Response of Bronchial Smooth Muscle to $MgCl_2$ *In Vitro*

MH Spivey, E Skobeloff, R Levin/Department of Emergency Medicine, Division of Research, The Medical College of Pennsylvania, Philadelphia; the Department of Urology, University of Pennsylvania, Philadelphia

Magnesium has been demonstrated to be an effective bronchodilator when given IV or by IM injection. The mechanism for this is unclear, but it has been postulated to act directly on the bronchial smooth muscle. Our study was designed to examine magnesium's effect on bronchial smooth muscle. Five-pound New Zealand rabbits were anesthetized with ketamine-xylozine and Nembutal®. The trachea and lungs were removed surgically and placed in oxygenated Tyrode's buffer. Three-millimeter bronchial rings were dissected and placed under 1g passive stretch in a tissue bath. Magnesium chloride added to the tissue bath in doses of 5, 10, 20, and 50 mM decreased mean ± SD resting tension by 60 ± 23, 10 ± 20, 60 ± 16, and 105 ± 44 mg, respectively. Electrical stimulation of 100 V, 100 ms increased mean tension by 168 ± 52 mg. Magnesium chloride (5, 10, and 50 mg) added to the bath decreased tension by 102, 127.5, and 168 mg, respectively. Histamine ($n = 4$) 10 mM increased the mean ± SD tension 490 ± 243 mg. Magnesium chloride (5, 10, and 50 mM) decreased the histamine response by 80 ± 113, 170 ± 147, and 475 ± 311 mg. Bethanecol ($n = 8$) 5 mM increased mean ± SD tension 495 ± 266 mg. Magnesium chloride (10 and 50 mM) decreased the bethanecol-induced tension by 132 ± 122 and 327 ± 237 mg, respectively. Magnesium chloride produced a dose-dependent relaxation of bronchial smooth muscle at rest and when stimulated by an electrical field, histamine, and bethanecol. These data support the hypothesis that magnesium-induced smooth muscle relaxation is responsible for the clinical improvement seen in patients who receive magnesium for acute bronchospasm.

146 Prospective Comparison of Inhaled Atropine and Metaproterenol in the Therapy of Refractory Status Asthmaticus

GP Young, P Freitas/Portland Veterans Administration Medical Center, Oregon Health Sciences University, Portland, Highland General Hospital, Oakland, California; University of California at San Francisco

We conducted a study of adults with refractory status asthmaticus to compare the response to inhaled anticholinergic with that to beta-adrenergic solutions. After failing to respond to standard therapies, 40 patients were randomized prospectively in a double-blind fashion to receive either 1.5 mg atropine (AT) or 15 mg metaproterenol (MP) by nebulizer. Both groups were similar in baseline characteristics, including mean FEV_1 measurements (0.70 L AT/0.60 L MP). Compared with baseline, the improvement in the FEV_1 for the MP group was statistically significant (31%, $P = .02$, paired t test), whereas the improvement in the AT group did not reach significance (10%, $P = .15$). Comparing the two groups, statistically significant differences favoring MP were found in the percent improvement in the FEV_1 (10% AT/31% MP; $P < .05$, signed rank) and in the percentage of patients improving their FEV_1 more than 10% above baseline (56% AT/81% MP; $P < .05$, chi-square). No patients in either group suffered any adverse outcomes. We conclude that for the majority of adults with refractory bronchospasm in status asthmaticus, an additional beta-adrenergic inhalation treatment results in more improvement than the addition of an atropine inhalation.

147 Adjunctive Use of Ipratropium Bromide in the Emergency Management of Acute Asthma

SM Tiernan, PK Cellucci, DJ Dire/Department of Emergency Medicine, Emergency Medicine Residency Program, Darnall Army Community Hospital, Fort Hood, Texas

Our study was undertaken to determine whether inhaled ipratropium bromide adds significantly to the bronchodilation obtained with inhaled beta-agonist alone in the setting of an acute asthma exacerbation. All patients who presented to our emergency department with an acute asthma attack with an initial FEV_1 of 25% to 75% of predicted were evaluated for enrollment in this double-blinded study. Patients less than 18 years old or with a history of glaucoma, urinary tract obstruction, chronic steroid dependence, emphysema, chronic bronchitis, or cigarette smoking were excluded. All patients received 2 mg terbutaline with 1 mL saline by a mininebulizer at 0, 60, and 90 minutes. Immediately after the first dose of terbutaline, patients in Group A received four puffs of ipratropium bromide administered by a metered-dose cannister with an interposed spacing device to standardize the dose. Patients in Group B received a placebo in the same manner. Repeat spirometry was performed on all patients immediately after the 60- and 90-minute terbutaline treatments. There were 20 patients in Group A who had an initial, 60-minute, and 90-minute mean FEV_1 of 48.9%, 63.3%, and 73.7% of predicted, respectively. There were 18 patients in Group B who had an initial, 60-minute, and 90-minute mean FEV_1 of 42.8%, 58.0%, and 68.3% of predicted, respectively. The initial, 60-minute, and 90-minute mean FEV_1 values for Group A and Group B were not statistically

different (P = .167, two-factor repeated measures ANOVA). The concurrent use of inhaled ipratropium and terbutaline does not result in a greater improvement in FEV_1 at 60 and 90 minutes over inhaled terbutaline alone.

148 The Utility of Extended Emergency Department Treatment of Asthma: An Analysis of Improvement in Peak Expiratory Flow Rate as a Function of Time

DG Murphy, RJ Zalenski, JC Raucci, N Dejneka, S Schabowski, M McDermott/Department of Emergency Medicine, Cook County Hospital; University of Health Sciences, The Chicago Medical School; Rush Medical College, Chicago, Illinois

We studied the efficacy of extended emergency department treatment time in achieving a PEFR of 50% predicted ($PEFR_{50}$). Achievement of $PEFR_{50}$ within three time frames was evaluated within four, four to eight, and eight to 12 hours of presentation. Entry into the study commenced when ED treatment was initiated. The PEFR was recorded hourly for up to 12 hours. Patients were categorized at presentation by the ratio of initial PEFR to predicted PEFR into group A (.40 to .49), group B (.30 to .39), group C (.20 to 29), and group D (less than .20). Included were patients aged 16 to 45 years. Excluded were pregnant women, those hospitalized, those with an acute comorbid illness, and those with initial PEFR of more than $PEFR_{50}$. The study group was 62% male and 90% black with a mean age of 28 years. Assignment of patients into severity groups yielded 41 (22%) patients in group A, 42 (23%) in group B, 47 (25%) in group C, and 36 (20%) in group D. Achievement of $PEFR_{50}$ required four to eight hours for 33 (18%) patients and required eight to 12 hours for seven (4%) patients. Group A had only one patient who needed more than four hours to achieve $PEFR_{50}$. Group B included 34 (18%) patients who achieved $PEFR_{50}$ within four hours, five (3%) who required four to eight hours, and three who needed eight to 12 hours. Group C included 28 (15%) patients within four hours, 16 (9%) within four to eight hours, and three requiring eight to 12 hours. Group D had 12 (7%) patients who achieved $PEFR_{50}$ within four hours, 11 (6%) needing four to eight hours, and only one patient who required eight to 12 hours. Nineteen (10%) patients were discharged from the ED without having achieved $PEFR_{50}$. Extending ED asthma treatment time in uncomplicated asthmatics for more than four hours yields a substantial increase in the percentage of patients reaching the therapeutic goal of $PEFR_{50}$. Only a small proportion of patients objectively benefited from more than eight hours of ED treatment time in this study group, and those who did so were not predictable on the basis of initial PEFR.

149 Evaluation of Brain Edema Using Quantitative Magnetic Resonance Imaging

JE Olson, A Katz-Stein, NV Reo, FA Jolesz, RVW Dimlich/ Departments of Emergency Medicine, Physiology and Biophysics, and Biochemistry and The Kettering-Scott Magnetic Resonance Laboratory, Wright State University School of Medicine, Dayton, Ohio; Department of Radiology, Brigham and Women's Hospital, Harvard Medical School, Boston; Departments of Emergency Medicine and Anatomy and Cell Biology, University of Cincinnati

Little is known about the mechanisms of brain water homeostasis. Consequently, current therapies for brain edema are limited to nonspecific and short-lived steroidal, osmolar, and diuretic modalities, treatments that are contraindicated in many emergency situations. In our study, we evaluated an animal model of cerebral edema using quantitative proton magnetic resonance imaging (MRI) techniques. T_2-weighted NMR images (TE, 80 ms; TR, 1 sec) were obtained from adult rats. After acquiring a baseline image, brain edema was produced by IP injection with a volume (V) of distilled water equivalent to 15% of the animal's body weight. Sixty minutes later, animals received 100 g/L NaCl IP in a volume equal to 0.1 (V). Control animals did not receive water or sodium chloride injections. The mean (± SEM) NMR image intensity of the brain increased by 10.7 ± 1.4% 60 minutes after the water injection ($N = 5$, $P < .001$) and then fell to control values 60 minutes after the sodium chloride injection. The mean intensity of images from control animals did not vary over this two-hour time period. In parallel studies, animals were injected with either 5% or 15% water and were sacrificed for determination of brain water content by specific gravity measurements or were fixed for electron microscopy. The mean (± SEM) cerebral gray matter water content increased from 80.9 ± 0.1% to 81.8 ± 0.2% ($N = 12$, $P < .005$) 60 minutes after a 5% water injection. Electron microscopy showed enlarged astrocyte end feet and extracellular spaces. Endothelial cells, neurons, axons, and myelin appeared normal. Brain water content decreased to control values 60 minutes after a sodium chloride injection. We conclude that MRI is a sensitive indicator for measuring small changes in brain water content in this animal model of brain edema. This technique may be used to study the time course of the removal of excess water during brain edema and to quantitatively evaluate potential specific treatments for brain edema present during pathological states.

150 Effect of High-Dose Norepinephrine Versus Epinephrine on Cerebral and Myocardial Blood Flow During CPR

JW Hoekstra, PF Van Ligten, R Neumar, HA Werman, J Anderson, CG Brown/Division of Emergency Medicine and Department of Preventive Medicine, The Ohio State University, Columbus

Several studies have demonstrated an improvement in cerebral blood flow (CBF) and myocardial blood flow (MBF) with large doses of epinephrine (E) during closed-chest CPR. The effects of similar doses of norepinephrine (NE) have not been studied. The purpose of our study was to compare the effects of high-dose E versus high-dose NE on CBF and MBF during CPR. Fourteen swine weighing more than 15 kg were anesthetized and instrumented for regional blood flow and hemodynamic measurements. After ten minutes of ventricular fibrillation CPR was begun using a mechanical thumper. After three minutes of CPR, the animals received either E 0.20 mg/kg (seven) or NE 0.20 mg/kg (seven) through a right atrial catheter. CPR was continued for an additional three minutes, and defibrillation was then attempted. CBF (mL/min/100 g), MBF (mL/min/100 g), myocardial oxygen delivery (MDO_2; mL O_2/min/100 g), myocardial oxygen consumption (MVO_2; mL O_2/min/100 g), and extraction ratios (ER; MVO_2/MDO_2) were measured during normal sinus rhythm, during CPR, and after drug administration. The results during CPR and after drug administration, including rates of successful resuscitation (SR; %), are displayed below. P values for E versus NE were calculated by analysis of covariance, adjusting for baseline differences during CPR.

	CPR	CPR + E	CPR + NE	P
CBF	1.0 ± 1.3	10.5 ± 4.4	17.3 ± 16.9	0.33
MBF	4.0 ± 2.9	62.2 ± 45.3	118.9 ± 73.1	0.04
MDO_2	0.6 ± 0.5	9.4 ± 6.3	19.9 ± 13.4	0.05
MVO_2	0.6 ± 0.5	7.0 ± 3.8	11.9 ± 8.6	0.10
ER	93.6 ± 5.5	78.2 ± 13.0	77.0 ± 13.4	0.74
SR		85.7	57.1	0.56

While NE improved MBF and MDO_2 over E, SR rates were lower with NE due to postdefibrillation arrhythmias in three of seven animals. Further study is required to delineate the mechanism of these arrhythmias with NE.

151 Cerebrovascular Occlusion: When Do Hemorrhagic Infarcts Develop?

GD de Courten-Myers, M Kleinholz, JA Wolker, KR Wagner, RE Myers/University and VAMC of Cincinnati, Ohio

Why hemorrhagic infarcts develop is poorly understood except for an association with embolic strokes. They are of interest because they may complicate fibrinolytic stroke treatment. Of 105 permanent and temporary middle cerebral artery (MCA) occlusions in cats, 83 developed infarcts, of which 26 (31%) were hemorrhagic with scattered petechial hemorrhages often coalescing to small hematomas affecting mainly grey matter. Hemorrhagic infarcts developed overwhelmingly in hyperglycemic (20 mM) compared with normoglycemic (6 mM) cats (ie, 25 of 58 or 45% compared with one of 25 or 4%; $P < .002$). Hemorrhages into infarcts occurred maximally (100%) in hyperglycemic cats with four and eight hour occlusions with reperfusion followed by 26% after permanent occlusion. The single hemorrhagic infarct in a normoglycemic cat occurred after an eight-hour temporary occlusion. The mean ± SEM infarct size (% MCA territory) was significantly smaller ($P < .05$) in 38 nonhemorrhagic (32 ± 5%) than in nine hemorrhagic infarcts (62 ± 12%) after permanent with even greater differences after occlusion followed by release (20 nonhemorrhagic, 12 ± 5%; 16 hemorrhagic, 83 ± 9%; $P < .001$). Two factors favoring the development of hemorrhagic infarcts emerge: hyperglycemia and restored blood flow after temporary occlusion. Hyperglycemia, by enhancing the tissue acidosis of ischemia, apparently exacerbates both central nervous system parenchymal and vascular damage, leading to