Neonatal-Pediatrics Bulletin
March/April '02

American Association for Respiratory Care

Newsflash: *At their March meeting, the AARC Board to Directors voted to re-name this section from Perinatal-Pediatrics to Neonatal-Pediatrics. Section Chair Timothy Myers said, "It shows the board recognizes the full range of practitioners working in the neonatal and pediatric specialties. Great news!"*

Notes from the Chair

by Timothy R. Myers BS, RRT

With the advent of spring, another busy viral season has come and gone for most children's hospitals. From what I have heard from colleagues around the country, it appears to have been a very busy RSV year for many of us. Hopefully, we will all have a few weeks to collect our wits and recuperate prior to the onset of the allergen-induced asthma exacerbations that many of our emergency departments experience in the spring season.

This year is shaping up to be a busy one for the neonatal-pediatric respiratory care community. The AARC's Clinical Practice Guidelines (CPG) Committee is undertaking the enormous task of reviewing and revising all existing CPGs over five years old. This will encompass approximately 6 to10 CPGs specific to our specialty. The committee will be looking for individuals with an interest in revising/updating these CPGs and/or in reviewing CPGs that have already been revised and updated. If you would like to participate in this endeavor, contact me at the address or numbers found on page 2.

I have also received word from the editorial staff of the RESPIATORY CARE journal that a Journal Conference specific to our specialty has been approved. The conference is set to take place in August at a yet-to-be-determined location. Topics to be covered include: asthma, RSV, cystic fibrosis, pediatric emergencies, ARDS, RDS, neonatal resuscitation, ECMO, diagnostic testing, neonatal and pediatric ventilation, specialty gas delivery and cardiopulmonary monitoring. Tentative publication date for the proceedings of the Journal Conference is early 2003.

I have recently reviewed neonatal/pediatric proposals submitted to the AARC for the International Respiratory Congress to be held in Tampa this October. All areas of our specialty and the diseases we treat on a daily basis were well represented in the proposals. While the final decisions on program content have yet to be made, I personally am looking forward to some exciting lectures and dynamic speakers discussing our specialty and the diseases we treat in Tampa. I encourage all of you to find your way to Tampa this fall to share in the International Congress.

As many of you are aware, every year the AARC Specialty Sections honor a Specialty Practitioner of the Year at the Awards Ceremony held during the International Congress. Some of the past winners from our section include Justin Twitchell, Jenni Raake, Michael Tracy, Esther Taylor and current *Bulletin* co-editor Kathy Deakins, who received the 2001 award. As the nomination deadline for 2002 approaches, I am looking for volunteers for the Section Recognition Committee, which will aid in the selection of our 2002 Practitioner of the Year. If you are interested in joining this committee, please contact me at the address (email or snail mail) or phone number listed on page 2 of this *Bulletin*. I also encourage all members to start brainstorming names of worthy candidates and preparing nominations for this award.

Lastly, I encourage all of you to consider contributing to your *Bulletin*. All you have to do to get started is contact co-editors Melissa Brown or Kathy Deakins at the addresses or numbers listed on page 2. And if you haven't already joined us on the neonatal-pediatric (new name, same great group) email listserve, please consider doing so. It's an excellent way to share ideas with your fellow section members. Recent topics have included RSV protocols, in-line MDI delivery, mist tents and neonatal ventilation.

Now, without further adieu, let's get on with some of the exciting articles in this edition of the *Bulletin*. ■

Notes from the Co-Editor

by Melissa K. Brown, RCP, RRT

I recently attended the Society for Critical Care Medicine (SCCM) conference held at the San Diego Convention Center. I always enjoy visiting the exhibit hall at these meetings and seeing all the great new and improved tools (some call them toys) for respiratory therapy. I was really struck this year by the advances in mechanical ventilators. Due to software-driven platforms, ventilators are evolving at an amazing pace. It's a very exciting time to be a respiratory therapist!

Indeed, one of the things I love about respiratory therapy is the constant opportunity for learning and professional growth. Ironically, the more I learn, the more I realize how much more there is to know. While I don't believe every new ventilator feature will prove to be clinically significant, I do believe some will improve patient comfort and minimize adverse events.

While in the exhibit hall, I had an interesting conversation with a vendor who was selling one of the more "basic" ventilators. His pitch to me was that the more advanced ventilator modes are a threat to the job security of respiratory therapists. He felt we would no longer be needed at the bedside if the interactive modes, such as dual-control and closed loop control, became the standard.

I wondered how many other clinicians he had tried to convince of this premise. I have found the exact opposite to be true. The more complicated the ventilators have become, the more valuable I am as a member of the patient care team. I spend many hours at the bedside educating other disciplines on mechanical ventilation. I think our ability to utilize and teach these advanced principles adds to our expertise and value. I find with each new feature, I am challenged to learn more about mechanical ventilation, and I gain a better understanding of how the equipment interacts with my patient. I doubt any respiratory therapist will lose a job due to a ventilator that is too advanced!

We have some great articles in this issue of the *Bulletin*. Jim Keenan, from Primary Children's Medical Center in Salt Lake City, UT, has written a fantastic article summarizing his research on the utilization of MDIs for medication delivery in neonatal and pediatric patients. Deciding how to best deliver medications in the NICU and PICU can be difficult, at best, and Jim's research provides excellent guidance. If you haven't met the amazing group of clinicians from Primary Children's, look for them at the AARC International Respiratory Congress in Tampa, FL, this October. Since they tend to travel in packs, I am sure you will see a half dozen of them providing lectures and presenting their papers in the Open Forums. They have provided impressive leadership in utilizing outcomes-based research to drive clinical practice, and they are always willing to share their findings with all of us. John Salyer has moved to Seattle, but he has left a tremendous legacy behind. Thanks to Jim, Kathy, Kim, John and all the rest!

We also have two very interesting articles from Charlie Diaz: a case study on intrapulmonary percussive ventilation (IPV) and a very detailed description of why IPV seems to be effective at resolving atelectasis. I have also seen positive results with this therapy. Several years ago, I heard about a hospital in town (my current employer) who was utilizing IPV in line with mechanical ventilation. After acquiring the policy and procedure, I mentioned it to my medical director during patient rounds. We were discussing a ten-year-old with cerebral palsy who had undergone spinal fusion and had failed extubation several times due to complete left lung collapse (and he had received every conventional therapy). The very next day he received IPV, his lung cleared immediately, and he was successfully extubated that same day.

I witnessed identical results in many other cases as well. After researching the literature, I could only find IPV studies in respect to cystic fibrosis management, but Kathy Deakins presented a paper discussing IPV in other conditions at the AARC Open Forum. The word appears to be spreading, and I would love to see more studies published on this application. Maybe, we can finally euthanize CPT!

Well, we can dream . . . ■

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American Association for Respiratory Care
11030 Ables Lane • Dallas, TX 75229-4593
(972) 243-2272 • FAX (972) 484-2720
e-mail: info@aarc.org

Debbie Bunch
Bulletin managing editor

Edwards Printing
Bulletin typesetting

Section Chair and Bulletin Editor
Timothy R. Myers, BS, RRT
Pediatric Administrative Mgr.,
Dept. of Respiratory Care
Rainbow Babies & Children's Hospital
Asthma CLinical Studies
Coordinator, Dept. of Pediatrics
Case Western Raserve University
11100 Euclid Avenue, #6020
Cleveland, OH 44106
(216) 844-1954
FAX (216) 844-5246
e-mail: timothy.myers@uhhs.com

Co-Editor s
Melissa K. Brown RCP, RRT
NICU Clinical Specialist
Pulmonary Services
Sharp Mary Birch Hospital for Woman
3003 Health Center Drive
San Diego, CA 92123
phone/voice mail (858) 493-1636
Fax (858) 541-3343
melissa.brown@sharp.com

Kathleen Deakins
Rainbow Babies and Childrens Hospital
11661 Mayfield Road
Chardon, OH 44024
(440) 285-5022
kathleen.deakins@uhhs.com

Resource Panel
Mike Czervinske, RRT
University of Kansas Medical Center
Department of Respiratory
Care Education
3901 Rainbow Blvd.
Kansas City, KS 66106-7606
(913) 588-4631
FAX (913) 588-4631
e-mail: mczervin@kumc.edu

Aerosolized and Meter Dose Inhaler Drug Delivery in Ventilated Neonatal and Pediatric Patients

by Jim Keenan, RRT, FAARC, technical manager, Primary Children's Medical Center, Salt Lake City, UT

Many studies have supported the use of meter dose inhalers (MDIs) over aerosolized drug delivery by small volume nebulizer (SVN) in adult ventilated patients. It has also been documented that the addition of some type of spacer device will increase drug availability. Among all drug deliveries tested, nebulized Albuterol and Ventolin in MDI formulation were the most abundant.

In institutions that care for ventilated neonatal and pediatric patients, we must ask whether the adult data are relevant to this population and if the same conclusions can be reached. There is no question that

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there are considerable differences between the way adults are ventilated and the way neonatal and pediatric patients are ventilated. Some of these differences are: ventilator circuit size, tidal volumes, flow-rates, pressures, inspiratory times and endotracheal tube (ETT) size and length. At Primary Children's Medical Center we felt it was necessary to reexamine the adult findings using neonatal and pediatric conditions.

When designing our studies, we varied neonatal and pediatric ventilator settings and ETT and circuit sizes. The drug was collected on filters at the end of the ETTs, and high performance liquid chromatography (HPLC) was used to determine drug totals. We accepted the conclusions from adult studies that supported the use of a spacer of some type when using MDIs to improve drug availability. Therefore, we always used a spacer when using an MDI.

One of our first studies was to compare nebulized Albuterol to Ventolin delivered via an MDI. In addition to comparing these two delivery methods, we wanted to assist clinicians in determining dose equivalency from Albuterol to Ventolin MDI. Our findings concluded that Ventolin MDI actuated into an in-line spacer delivers approximately 5.25% (+ 0.05%) drug compared to 0.15% (+ 0.5%) of a nebulized dose of Albuterol. This is a significant finding because more drug is available using an MDI with spacer than using nebulization. We also determined in our studies that a single actuation of Ventolin delivered the equivalent of nebulizing approximately 3.0 mg of Albuterol.

The responses we received to our first study indicated that many practitioners take the patient off the ventilator, place the spacer on the end of the ETT, and "hand-bag" deliver the MDI. Others place the spacer on the end of the ventilator circuit wye, attach it to the ETT, and actuate the MDI during mechanical ventilation. We studied the differences between these two delivery methods. We concluded that approximately 5.25% (+ 0.5%) Ventolin was delivered during mechanical ventilation and that approximately 5.65% (+ 2.25%) was delivered during manual "hand-bagging." These delivered amounts are not significantly different, but it is important to note the broad range of drug availability during "hand-bagging." "Hand-bagging" is practitioner-specific, producing variations in inspiratory times, tidal volumes, rates and pressures to effect drug availability.

Many spacer manufacturers suggest that their spacer be placed in the ventilator circuit's inspiratory limb. When continuous or bias flow is present in the circuit with neonatal and pediatric modes of ventilation, most, if not all, of the medication actuated from the MDI into the spacer will bypass the patient. This concern has led clinicians to place the spacer on the end of the ETT and either "hand-bag" or allow the mechanical ventilator to deliver the actuated MDI medication (as discussed). This has led to yet another discussion. Does a large volume spacer introduced at this location result in CO_2 retention due to mechanical dead space? Spacers have anywhere from 50-150 mL of dead space compared to neonatal tidal volumes, which can be as low as 1 mL. Some neonatal practitioners recognize the benefit of MDIs over nebulization but choose not to use them because of the dead space concern.

We developed a lung model with the ability to exhale 7.1% CO2 or approximately PCO_2 = 48 mm Hg. We evaluated exhaled tidal volumes of 7, 15 and 25 mLs at varying ventilation rates and inspiratory times. An end tidal CO2 monitor was incorporated into the spacer. Readings were recorded every 30 seconds, up to a total of 4 minutes. We found that some CO_2 accumulation does occur, but these amounts are not clinically significant even when left in line as long as 4 minutes. We concluded that it is safe to use spacers at this location when using small tidal volumes.

The studies at Primary Children's Medical Center conclude that MDI with spacer enhances drug delivery in ventilated neonatal and pediatric patients. This research has changed clinical practice in our facility.

Bibliography on the above and other related studies are available upon request. ■

Treatment of Atelectasis with IPV in the Pediatric Patient

by Charlie Diaz, RRT, Children's Mercy Hospitals and Clinics, Kansas City, MO

In most infants and small children who require mechanical ventilation, conventional respiratory care interventions, hyperinflation, bronchial hygiene and aerosolized medication delivery are sufficient to maintain airway patency. Nevertheless, atelectasis continues to be the most frequent complication of mechanical ventilation within this population (Tausig). Atelectasis is defined as:

1. An incomplete expansion of a lung or portion of a lung, occurring congenitally as a primary or secondary condition or as an acquired condition.
2. Airlessness of a lung that once had been expanded.
3. Collapse of the lung.

Secondary atelectasis is the most common form in the pediatric population and arises from the preferential ventilation of the airways.

In the mechanically ventilated patient, preferential airway ventilation will occur whenever the tidal volume delivered to the proximal airways of the patient with an inspiratory flowrate exceeds the time constant for the airway. Therefore, the resistance to flow will convert the flow to pressure. This conversion creates a proximal to distal pressure gradient. Whenever this inflow pressure gradient exceeds the flow required for a near laminar inflow into the locus of peripheral airway bifurcations, the flow available to low resistance peripheral airways increases while that for high resistance airways decreases. Therefore, ventilation becomes increasingly preferential. Further, due to the lung's interdependence, through collateral ventilatory channels, the so-called pendelluft effect (gas flow between different regions of the lung caused by pressure gradients caused by time constant inequalities) occurs as expansionary forces develop around the high resistance airways from the expansion of the surrounding parenchyma. Management of this condition must be focused on the relief of the obstruction/restriction, which may only be accomplished with careful examination and application of the physiological principles responsible for ventilating obstructed regions of the lungs.

In 1893 H. Kohn reported that there were collateral communicating pores between alveoli (Tausig p. 1198). Then, in 1930 Van Allen and Jung described the concept of interdependence within the lung through collateral ventilation. Further, in 1934, Van Allen and Jung demonstrated that the atelectatic lung could be re-inflated utilizing these collateral channels (Mackenzie Colin CPT in the ICU p. 26 from Anderson jb 1979). In 1957 Lambert described communications between peripheral bronchioles, hence the canals of Lambert (Lambert MW: Accessory bronchiolo-alveolar channels, Anat. Rec 127:472, 1957).

In 1979, F. M. Bird recognized the limitations associated with intermittent positive pressure breathing (IPPB) - in terms of airway recruitment - to be the lack of expira-

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tory airway support during passive expiratory flow and the end resting position, which allowed the obstructive airway to occlude between each scheduled positive pressure inflationary cycle. Therefore, most IPPB therapy performed without utilizing CPAP as an expiratory airway-stabilizing factor had a minimal accumulative effect in terms of the maintenance of airway caliber between successive inspiratory positive pressure inflations.

F. M. Bird pioneered adjustable inspiratory flowrates, which first appeared on the Bird Mark series of respirator prototypes in the early 1950s. The later Bird Mark 9 Super Respirator had inspiratory flowrates sufficiently high to fire the Hering Breur (stretch) receptors when tidal volumes were delivered above threshold velocities. During the early attempts to develop a higher frequency ventilator with percussive inflow delivery potentials, F.M. Bird was again confronted with firing of the Hering Breur (stretch) receptors, as well as inadvertent PEEP, increasing with delivery frequency.

In the early 1980s champions of pure diffusive high frequency ventilation advanced its ability to increase PaO_2 in laboratory animals. Knowing CO_2 was some 20 times more diffusable than oxygen, they took for granted that the CO_2 would be concomitantly eliminated. What these researchers did not realize was that because endobronchial viscous resistance created friction to the shock waves during endobronchial passage, a massive fade out of amplitude occurred before the diffusive shock wave reached the distal pulmonary airways. Therefore, without a balanced convective exchange to wash out CO_2, the patient could potentially die nice and pink of a CO_2 narcosis. Jet ventilation (insufflation), often called high frequency ventilation, followed pure high frequency with similar claims. A jet ventilator did not have an exhalation valve and was dependent upon an airway leak around the indwelling airway catheter. This limited jet ventilation to patients with very compliant lungs because the maximum pressure rise was mandated to under 15cm H_2O to prevent high levels of inadvertent PEEP.

Armed with the limitations of IPPB and the early concerns in the development of high frequency ventilation (HFV) protocols, Bird developed the concept of intrapulmonary percussive ventilation (IPV) to overcome these quandaries. IPV provides for a combination of therapeutic regimens specifically directed toward the amelioration of the components of airway obstruction. IPV creates repeated percussive pressure differentials at the proximal airway, with sufficient amplitude to affect intrapulmonary overlapping sub tidal volume deliveries without firing the Hering Breuer (stretch) receptors embedded within the pulmonary structures. These percussive pressure differentials, coupled with a sustained inspiratory flow gradient and near instantaneous flow reversals, are provided by a servoed sonic venturi injector/exhalation valve called a phasitron.

The design of the phasitron's physiological/mechanical interface facilitates internal percussion of the lung at higher frequencies, without the development of inadvertent PEEP. By allowing for a gradual step inflation of the pulmonary structures through percussive sinusoidal inspiratory flow gradients, the lungs are more uniformly inflated. This step inflation of the lung reduces preferential airway ventilation by creating a more uniform alveolar inflation and thus a more effective blood gas interface. Following the step inflation of the lung unit, percussive sub tidal volume deliveries are continued at frequencies from 100 to 300 cycles per minute with an I/E ratio of 1:2.5. Once the lungs are percussively step inflated, they are then maintained by a percussive intrapulmonary sub tidal exchange at a dynamic functional residual capacity (D/FRC) while allowing the patient the freedom to spontaneously breathe, shifting his or her lung volumes at will. During the post inspiratory percussive apneustic equilibrium, peripheral respiratory gases are percussively mixed through the maintenance of patent airways created by the 1:2.5 I/E ratio, which provides for a slight continuous positive airway pressure (CPAP) between percussive sub tidal volume deliveries at rapid rates without further increases in lung volumes.

The theory of IPV/CMV combines the serialized convective intrapulmonary pressure rises of continuous mechanical ventilation (CMV) with the higher frequency percussive sub tidal programming of IPV. This combination creates a "step inflation" of the pulmonary structures by using the tidal exchange of the CMV ventilator to "transport" the IPV wave into the pulmonary structures. By providing for the "oscillatory percussive enhancement" of existing CMV with IPV, the baro-traumatic consequences of existing volume/pressure scheduled ventilation can be effectively obtunded in typical patient populations, as described in the NIH studies which were published in May of 2000 in the *New England Journal of Medicine* ("Ventilation with Lower Tidal Volumes as Compared with Traditional Tidal Volumes for Acute Lung Injury and the Acute Respiratory Distress Syndrome," Vol. 342, No.18) .

This reduction in the baro-traumatic potential is accomplished by producing a step inflation of the lung to decrease the "acute proximal/distal inspiratory flow gradient" into the dependent pulmonary structures. The greater the proximal distal pressure/flow gradient into the lung, the greater the preferential airway and associated potential trauma within the most dependent peripheral lung structures. During CMV, inspirational pressures are held against the pulmonary structures in seconds, as opposed to IPV, where the cyclic percussive pressure rises are held in milliseconds. This is analogous to driving the tidal volume into the lung with a "sledge hammer" with one blow; as opposed to gradually inflating and deflating the lung with mini volume deliveries, which gradually "tap inflate and deflate" the elastomeric intrapulmonary structures. Therefore, peripheral airway collapse does not occur with IPV/CMV because of the automatic peripheral intrapulmonary wedge pressure factored by the percussive rate and a slightly positive I/E ratio, which serves to stabilize the peripheral airways between the percussive higher frequency sub tidal deliveries. Therefore, the phasic "frictional rub" within airways with diameters below 2 mm, created by phasic CMV scheduling, is eliminated by the expiratory peripheral intrapulmonary stabilization secondary to IPV/CMV programming.

An additional benefit is the enhancement of the mechanical vesicular peristalsis, a factor of the acute (near instantaneous) percussive pressure rise and drop within the intrathoracic bronchial, pulmonary and lymph circulation. This creates an enhanced directional fluid flow through this circulation. By maintaining a peripheral intrapulmonary wedge pressure, the smaller airways are held open during IPV/CMV inspiratory/expiratory phasing, negating the frictional abrasion associated with CMV programming. The acute phasic pressure "transitions" within the larger conducting airways create the pressure differentials for the enhancement of "physiological vesicular peristalsis" by "mechanical vesicular peristalsis."

Essentially, the CMV ventilator, whether it is volume or pressure cycled, provides for the phasic "gross change" in lung volume to effect the convective wash out of CO_2. The IPV Percussionator creates a major intrapulmonary percussive gas mixing for "oxygen delivery and carbon dioxide recruitment." This tends to reduce the required peak tidal delivery pressures, as well as FiO_2. Further, the substitution and/or mixing of expiratory OD/CPAP for or with PEEP can result in favorable peripheral pulmonary airway stabilization

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with less impaction upon cardiac output.

(Note: Demand CPAP maintained a selected expiratory baseline if the patient should spontaneously create an inspiratory effort. Demand CPAP provided a major means of airway stabilization and greatly decreased the work of breathing during weaning. Demand CPAP can be compared to PEEP in the apneic patient.)

It must be clearly understood that IPV is not an alternative form of high frequency ventilation. There are vast differences in the physical principals involved, as well as the potential clinical efficacies. With an understanding of the methodology employed to percussively ventilate potentially obstructive pulmonary structures via a mechanically programmed combination of inspiratory percussion and expiratory CPAP, followed by an augmented passive expiratory outflow, the premise of IPV is revealed. The step inflation of the lungs with sub tidal volumes, followed by the serialized delivery of "block volumes" into the lungs during the percussive post inspiratory exchange, provides for an ideal means of effectively transporting a therapeutic aerosol throughout the pulmonary fields while maintaining an effective mechanical ventilation.

Therefore, the components of IPV are the percussive step inflation of the lung, stabilization of the bronchi between percussive sub tidal volume deliveries with CPAP, post inspiratory percussive intrapulmonary mixing of respiratory gases, enhanced passive expiratory flowrates enabling the cephalad transport of mobilized secretions and delivery of therapeutic aerosols from the proximal pulmonary airways into the smallest parenchymal bronchi. In the end, as with all therapeutic modalities, the most cost effective protocol with the highest level of continued clinical efficacy with minimal toxicity must be the regimen of choice. ■

IPV Case Study

by Charlie Diaz, RRT, Children's Mercy Hospitals and Clinics, Kansas City, MO

A 13-year-old female presented to our emergency department with a gunshot wound to the neck. The wound was a "through and through," involving both trachea and esophagus. Additionally, she had suffered a vertebral fracture at thoracic vertebra #4, that resulted in a complete transaction of her spinal cord with subsequent quadriplegia. She was taken to the operating room for surgical intervention and ultimately admitted to our pediatric intensive care unit. The patient was extubated in the morning of Post OP day 1. Throughout the morning the patient developed increasing respiratory distress. A chest x-ray was obtained revealing a total collapse of the left lung.

The patient was reintubated and returned to mechanical ventilation with previous settings. Post intubation film demonstrated continuing total left lung collapse.

Percussion and postural drainage were ordered for Q2 hours. Post OP day 2's morning chest film continued to show total left lung collapse.

Fiberoptic bronchoscopy was performed but was unable to reach the plug. Orders were to continue Q2 percussion and postural drainage. Post OP day 3's morning chest film continued to show total left lung collapse.

IPV was started Q2 hours. A chest x-ray was taken after 2 treatments, showing reenflation of the left lung.

The patient was weaned and extubated within 2 hours. The following morning the patient was transferred to the general care wards without further respiratory complications.

The concept of IPV was first advanced in 1981. F. M. Bird, MD, PhD, defined IPV as a novel methodology directed toward the resolution of pulmonary atelectasis, as well as the mobilization and elimination of retained endobronchial secretions. IPV is an FDA approved device that provides a combination of therapeutic regimens, including high-density aerosol delivery, percussive step inflation of the lung and stabilization of the airways. Through this sequential inflation process collapsed airways are re-recruited. After recruitment the airways are stinted open by the application of CPAP, further enhancing airway recruitment through the collateral ventilatory channels. Utilizing these collateral channels, pressure is applied within the collapsed units, thereby equalizing the pressure differential within the airways and enhancing mucociliary clearance. ■

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To change your option to the electronic section *Bulletin*, send an email to: mendoza@aarc.org. ■

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