Treatment of mandibular osteomyelitis in two red-necked wallabies (Macropus rufogriseus) by means of intensive long-term parenteral drug administration and serial computed tomographic monitoring

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A 2-year-old female captive-born red-necked wallaby (Macropus rufogriseus; case 1; body weight, 11.06 kg [24.33 lb]) was evaluated because of sudden-onset mandibular swelling, ptalism, and hyporexia. The wallaby had been housed with 9 other wallabies, 7 western gray kangaroos (Macropus fuliginosus), and 2 emus (Dromaius novaehollandiae) in a 0.3-hectare (0.8-acre) pasture with access to a 38.8-m (127-ft) X 3 X 2-cm swelling with a fluctuant center of the ventral aspect of the left mandible. Radiography revealed a soft tissue mandibular swelling with osteolucency around mandibular incisor roots in both wallabies. Computed tomography revealed changes consistent with chronic active mandibular osteomyelitis and reactive bone formation, but also sequestra formation not appreciable via radiography.

TREATMENT AND OUTCOME

Long-term antimicrobial treatment was initiated with clindamycin (17 to 21 mg/kg [7.7 to 9.5 mg/lb], IV, q 12 h for 40 to 55 days) and high-dose benzathine penicillin G (80,000 U/kg [36,364 U/lb], SC, q 12 h for 150 days). Serial CT was performed to evaluate response to treatment and resolution of disease. A CT scan 18 months after the initial evaluation revealed complete resolution of osteomyelitis and sequestra.

CLINICAL RELEVANCE

Advanced imaging and long-term treatment and management were integral to the successful outcome for these wallabies, given that the osseous changes visible on CT images were not visible on standard radiographs, guiding therapeutic decision-making. This report provides new therapeutic and diagnostic monitoring information to assist clinicians with similar cases.

CASE DESCRIPTION

2 female red-necked wallabies (Macropus rufogriseus) were evaluated because of sudden-onset mandibular swelling, ptalism, and hyporexia.

CLINICAL FINDINGS

Physical examination revealed a mandibular swelling with a fluctuant center in both wallabies. Hematologic analysis revealed leukocytosis with a mature neutrophilia and monocytosis in one wallaby (case 1) and a slight neutrophilia, hyperglobulinemia, and high serum alanine aminotransferase activity in the other (case 2). Cytologic examination of the swelling revealed a uniform population of gram-negative rods in case 1 and neutrophilic inflammation in case 2. Radiography revealed a soft tissue mandibular swelling with osteolucency around mandibular incisor roots in both wallabies. Computed tomography revealed changes consistent with chronic active mandibular osteomyelitis and reactive bone formation, but also sequestra formation not appreciable via radiography.

ABBREVIATIONS

CCFA Cefotiofur crystalline-free acid
MMA Methylmethacrylate
flushed with dilute betadine solution and left open to drain. Treatment was initiated with meloxicam\(^c\) (0.2 mg/kg [0.09 mg/lb], PO, q 12 h for 12 days), CCFA\(^i\) (8.0 mg/kg [3.6 mg/lb], SC, once), and enrofloxacin\(^f\) (9.26 mg/kg [4.2 mg/lb], PO, q 24 h for 10 days). After recovery, the wallaby was returned to the exhibit and monitored daily.

Cytologic examination of the purulent material revealed a uniform population of gram-negative rods. Microbial culture yielded a pure growth of *Fusobacterium* spp. Results of CBC and serum biochemical analysis indicated leukocytosis (9,200 cells/µL; reference mean ± SD, 5,880 ± 2,160 cells/µL),\(^1\) with mature neutrophilia (5,704 cells/µL; reference mean ± SD, 1,976 ± 1,153 cells/µL),\(^1\) mononcytosis (736 cells/µL; reference mean ± SD, 217 ± 274 cells/µL),\(^1\) and hyperglobulinemia (3.9 gm/dL; reference mean ± SD, 2.2 ± 0.8 gm/dL).\(^1\)

On days 7 and 12, the wallaby was reevaluated while anesthetized because of ongoing facial swelling and unsatisfactory response to treatment. Hematologic analysis was performed again, revealing no clinically important changes. The mandibular swelling had reduced in size but remained prominent. Purulent material could be expelled, and the abscess was again drained. Radiography revealed additional lysis at the apex of the left mandibular incisor tooth and bony reaction (opacity) around the root of the right mandibular incisor tooth. The left mandibular incisor tooth was extracted, and an MMA bead impregnated with cefazolin\(^a\) was placed into the sulcus in an effort to increase the antimicrobial concentration at the site of infection. Ampicillin\(^b\) (30 mg/kg [13.6 mg/lb], IM) and meloxicam (0.2 mg/kg, SC) were also administered while the wallaby was anesthetized.

Additional microbial culture of the purulent material from the abscess yielded *Prevotella* spp, and antimicrobial treatment was adjusted on the basis of susceptibility testing to include florfenicol\(^c\) (30 mg/kg, IM, q 12 h for 14 days) followed by amoxicillin trihydrate–clavulanate potassium\(^f\) (11.36 mg/kg [5.2 mg/lb], PO, q 12 h for 14 days).

On day 60, the wallaby was reevaluated while anesthetized for reassessment of the soft tissue swelling and follow-up radiography. Hematologic analysis revealed a moderate leukocytosis (6,700 cells/µL),\(^1\) mature neutrophilia (2,948 cells/µL),\(^1\) and hyperglobulinemia (3.0 g/dL).\(^1\) The fluctuant soft tissue swelling had resolved, but a firm bony swelling remained. Despite the unremarkable appearance of the mucosa covering the site of the previous extraction, radiography revealed progressive bony proliferation and lucency at the sulcus of the left mandibular incisor tooth and the rostral aspects of the left and right mandibles, suggesting ongoing mandibular osteomyelitis (Figure 1). The MMA bead was no longer visible.

Three core biopsies were performed by use of a 13-gauge bone marrow biopsy needle,\(^1\) and biopsy specimens were collected and submitted for histologic examination. Histologic findings confirmed osteomyelitis with moderate bony remodeling and fibrosis. During the biopsy procedure, the joey was removed from the pouch to be hand reared to prevent potential injury during repeated handling of the doe. Antimicrobial treatment was adjusted on the basis of recommendations for treatment of *Fusobacterium* dental infections in humans.\(^2\) Long-term parenteral administration of clindamycin\(^b\) (17 to 21 mg/kg [7.7 to 9.5 mg/lb], IV, q 12 h for 40 days) and benzathine penicillin G\(^c\) (80,000 U/kg [36,364 U/lb], SC, q 12 h for 150 days) was initiated. Intravenous injections were administered into the lateral tail vein via a 19-gauge, 11-cm-long line catheter,\(^c\) which was secured to the tail with bandaging tape.\(^c\) The catheter was replaced with the wallaby manually restrained as needed when phlebitis or catheter occlusion was detected. Vascular health was assessed with each catheter replacement. Bandages covering the catheter were changed daily with the wallaby manually restrained.

On day 90, radiography confirmed a decrease in the previous amount of bony reaction and proliferation and no additional lucency. Hematologic analysis was performed at each recheck examination, and unless noted, no clinically important changes were observed.

A CT scan\(^c\) of the head was performed, with settings of 100 kV, 80 mA, and 1.5 s/rotation; 1-mm contiguous images were reconstructed by use of bone

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**Figure 1**—Right lateral oblique radiographic image of the head of a 2-year-old female red-necked wallaby (*Macropus rufogriseus*; case 1) obtained 60 days after initial evaluation (day 0) for mandibular swelling, Ptyalism, and hyporexia. Marked smooth bone proliferation is visible along the ventral aspect of the left mandible (white arrows) as well as a central draining tract (black arrow).
and detail algorithms. A baseline CT scan (Figure 2) performed 8 months earlier during a preventative care examination had revealed no evidence of osteomyelitis and was used as a normal comparison for subsequent CT scans. The CT scan on day 90 revealed several osseous fragments in the alveolus of the extracted left mandibular incisor tooth that were separated from the mandible and considered sequestra. From the region of the remaining alveolus, an area of poorly marginated hypoattenuation channeling was visible caudolaterally through the bone proliferation that was considered a draining tract originating from the mental foramen. Marked bone proliferation with poorly defined bone proliferation in 3-D reconstructions of the left mandible, and to a lesser extent, the right mandible (Figure 3). Widening of the alveolus at the tip of the root of the right mandibular incisor tooth was also apparent. These findings supported the previous diagnosis of chronic active left mandibular osteomyelitis and mild chronic right mandibular reactive bone formation, but further results indicated sequestra formation that had been unappreciable via radiography.

Computed tomography was repeated on day 120 with and without contrast medium administration (iohexol at 600 mg/kg [272.7 mg/lb], IV), revealing
that the left incisor alveolus had remodeled and was mostly filled with amorphous mineral-attenuating material. The smooth bone proliferation along the ventrolateral aspect of the right mandible from the rostral tip to the level of the first molar had mildly increased in circumference since the scan on day 90, but had remodeled and had cortex-like margination. The mild widening at the root of the right mandibular incisor tooth remained static on this and subsequent examinations. Findings were consistent with continued improvement with well-defined bone margins, a decrease in soft tissue swelling, and no evidence of the signs of active mandibular osteomyelitis or sequestra. The high degree of detail provided by CT confirmed clinical improvement and supported the apparent clinical effectiveness of parenteral antimicrobial treatment. At this time, clindamycin administration was discontinued whereas benzathine penicillin G administration was continued twice daily.

Examination of the wallaby on day 210 confirmed a further decrease in the mandibular swelling with no evidence of abscess formation. A CT scan (Figure 2) revealed continuous remodeling of the mandibular periosteal proliferation with smoothing of the periosteal proliferation. However, new bone proliferation in areas of the left mandible that had been previously mineralizing contained a poorly delineated region of decreased and mottled attenuation with small mineral fragments present. This was considered a new focus of osteomyelitis with sequestrum formation, prompting continued parenteral benzathine penicillin G administration.

Serial CT imaging was performed on days 240, 270, and 300 to reevaluate the sequestra and monitor response to treatment. Bone remodeling along the mandibles continued to smoothen and reduce in size, with distinct margination. The area of lucency in the rostral aspect of the left mandible increased slightly in size but was well marginated. The small osseous sequestra in the center of the left mandible were less defined and appeared subjectively smaller. At this time, antimicrobial administration was discontinued (after 150 days of treatment and 300 days after initial evaluation). A final CT scan performed 18 months after initial evaluation revealed no evidence of ongoing or recurrent dental disease and full resolution of the osteomyelitis and sequestra (Figures 2 and 3).

A second captive-born, 3-year-old female red-necked wallaby (case 2; body weight, 10.1 kg [22.2 lb]) from the same enclosure was evaluated 2 weeks after the first wallaby because of sudden-onset swelling of the right mandible, ptyalism, and hyporexia (day 0). Examination by use of the previously described anesthetic protocol revealed a fluctuant swelling over the proximal, ventral aspect of the right mandible and 2 open lesions within the oral cavity: 1 within the intermandibular space and another along the lateral edge of the ramus of the right mandible. The crowns of the left maxillary second premolar and deciduous third premolar teeth were loose, easily extracted, and not related to any areas of infection and appeared to be consistent with physiologic molar progression in this species. Radiography of the head revealed an intermandibular soft tissue swelling measuring 3 X 2 cm, with a mild lytic area associated with the root of the right mandibular incisor tooth. The mandibular swelling was aseptically prepared and incised, and purulent material was expressed. The abscess was flushed with warm diluted chlorhexidine diacetate solution and left open to drain.
A CBC and serum biochemical analysis revealed a slight neutrophilia (4,420 cells/µL), hyperglobulinemia (4.6 gm/dL), and high serum alanine aminotransferase activity (129 U/L; reference mean ± SD, 37 ± 19 U/L). A CT scan was performed 1 week after the initial evaluation with the same protocol used as for case 1. Review of the images confirmed osteolysis at the base of the right mandibular incisor tooth, consistent with a dental abscess, and periosteal proliferation along the ramus of the right mandible (Figure 4).

Cytologic examination of a fine-needle aspirate sample obtained from the purulent material from the abscess revealed marked, degenerate neutrophilic inflammation consistent with an abscess and suppurative inflammation, with large numbers of mixed bacteria. Microbial culture yielded Actinomyces spp, Prevotella spp, and Eggerthella lenta. The wallaby was treated with meloxicam (0.2 mg/kg, SC initially and then PO, q 24 h for 30 days), CCFA (8.8 mg/kg [4 mg/lb], IM, q 4 days for a total of 3 doses), trimethoprim-sulfamethoxazole (20 mg/kg [9.1 mg/lb], PO, q 12 h for 14 days), and tramadol (1 mg/kg [0.45 mg/lb], PO, q 12 h for 5 days).

On day 21, the right mandibular incisor tooth was removed because of progressive lysis identified via radiography. Histologic examination of the tooth confirmed periodontal inflammation and localized osteomyelitis. The edge of the alveolar bone was markedly irregular and scalloped. With 1 simple interrupted suture, the sulcus was closed. Two cefazolin MMA beads were placed in the ventral mandibular abscess and held in place with 3 simple interrupted sutures.
that still allowed the abscess to drain. The beads were left in place for 2 weeks. Recheck CBC revealed a moderate leukocytosis, low Hct (31%; reference mean ± SD, 46.1 ± 7.1%), and slight erythrocytosis (4.00 × 10⁶ RBCs/μL; reference mean ± SD, 3.31 × 10⁶ RBCs/μL ± 0.73 × 10⁶ RBCs/μL). The wallaby was treated with cefazolin (20 mg/kg, IV), meloxicam (0.3 mg/kg [0.14 mg/lb], SC), and CCFA (8 mg/kg [3.6 mg/lb], IM).

By day 30, slight submandibular swelling remained; however, no ptalism was evident and appetite appeared good. With the wallaby anesthetized, purulent material was easily expressed from the right mandibular incisor extraction site and a second, firm, round swelling was detected caudal to the initial abscess on the ramus of the right mandible. The initial lanced abscess site was packed with iodine-soaked gauze. The caudal swelling contained fetid, purulent exudate and was packed with betadine-soaked umbilical gauze. Seven days of treatment with meloxicam (0.3 mg/kg, PO, q 24 h) and enrofloxacin (9.51 mg/kg [4.3 mg/lb], PO, q 24 h) was provided on the basis of the results of microbial culture and antimicrobial susceptibility testing for case 1. No antimicrobial susceptibility testing of cultured isolates was performed for case 2. Hematologic analysis was repeated with each recheck examination, and unless otherwise noted, no clinically important changes were observed.

On day 45, a follow-up CT scan was performed, revealing considerable osteolucency of the distal portion of the right mandible, soft tissue filling of the extracted tooth alveolus, and periosteal reaction extending caudally along the mandibular ramus (Figure 4). Mild bone reaction with 1 small potential focus of lysis was also visible on the medial aspect of the left mandible. Because of the progressive osteolucency, the wallaby was hospitalized for more intensive long-term parenteral treatment. Antimicrobial administration was adjusted on the basis of susceptibility test results for the original isolates to clindamycin (17.48 mg/kg [7.9 mg/lb], IV, q 12 h for 60 days) and benzathine penicillin G (80,000 U/kg, SC, q 12 h for 150 days), representing the same protocol as for case 1. For case 2, treatment at this point also included meloxicam (0.22 mg/kg [0.1 mg/lb], SC, q 24 h for 21 days), chloramphenicol MMA beads (on the basis of susceptibility test results from case 1), and iodine-soaked gauze applied topically within the draining mandibular abscess.

A CT scan performed on day 90 revealed that the remaining alveolus of the right mandibular incisor tooth was filled with slightly hypointensuating mineral material, and mild smooth bone proliferation was visible along the ventrolateral margin of the mandible. Both of these findings were consistent with chronic and minimally active healing mandibular osteomyelitis of the right mandible. On day 104, CT revealed that the remaining alveolus was almost completely filled with mineral-attenuating material, which approached the attenuation of the remaining mandibular medulla (Figure 4). Bone proliferation along the ventrolateral margin of the right mandible had mildly increased in circumference yet remodeled, as indicated by cortex-like margination. A reduction was evident in the extent of soft tissue swelling that overlaid the bony changes. The right mandibular osteomyelitis was minimally active, with evidence of mild remodeling without progression. These CT findings confirmed continued improvement with no evidence of active mandibular osteomyelitis and a decrease in the amount of soft tissue swelling, with well-defined bone margins.

A final CT scan was performed on day 210, revealing progressive healing with no evidence of active mandibular osteomyelitis or further lytic processes, with minimal overlying soft tissue swelling (Figure 4). Treatment was continued for an additional 3 months owing to the difficulty encountered when attempting to distinguish remodeling from osteolucency associated with new lesions on follow-up CT scans. A CT scan performed before the wallaby was returned to the exhibit revealed changes consistent with continued improvement.

**Discussion**

In the red-necked wallabies of the present report, successful treatment of advanced mandibular osteomyelitis was achieved by use of serial CT imaging to monitor the effectiveness of and guide intensive parenteral antimicrobial treatment. Dental disease is common in macropods (including red-necked wallabies) housed in zoological collections, contributing considerably to morbidity and mortality rates.

Most macropods have specialized molar progression. The rostral cheek teeth occlude initially, and as these teeth wear down, the more caudal teeth move rostrally to replace the worn rostral molar teeth. Red-necked wallabies are intermediate browser-grazers and possess a deciduous third premolar tooth (dental formula: I 3/1; C 0/0; P 2/2; M 4/4).

Oral necrobacillosis or lumpy jaw is caused by gram-negative, anaerobic bacteria, including *Fusobacterium necrophorum* and *Bacteroides* spp. Risk factors include stress from overcrowding, inadequate nutrition, trauma from abrasive or poor-quality food material, and trauma to the incisor teeth or rostral portion of the mandible or maxilla. The most common clinical signs are mandibular or facial swelling and epiphora, ptalism, halitosis, unilateral ocular discharge, and weight loss. The disease is difficult to treat, with a low (16%) survival rate reported for red-necked wallabies.

Other than rostral trauma, none of the risk factors for mandibular osteomyelitis in macropods were recognized in the red-necked wallabies of the present report. The wallabies shared a large outdoor enclosure with other wallabies, were allowed indoor access, and were maintained on a well-balanced, high-quality diet. The organisms recovered from the lesions included *Fusobacterium* spp, *Prevotella* spp (previously *Bacteroides* spp), and *Actinomyces* spp.
These organisms, as well as *Eggerthella lenta* recovered from case 2, are common anaerobic enteric organisms that have been identified as opportunistic pathogens in humans and other animals, particularly in the oral cavity.¹⁻⁶,¹ⁱ,¹³,¹⁶ Enteric bacteria are continuously introduced to the mouths of macropods as they feed from the ground,¹³ and this was considered the most likely route of exposure to these organisms in the wallabies.

Treatment of mandibular osteomyelitis in macropods is challenging for many reasons, including the stress associated with repeated manual restraint for examination and drug administration.³⁻⁵ It is also common for mandibular osteomyelitis to recur, requiring repeated treatments.⁵,¹³ We speculate, however, that recurrence is more likely recrudescence of the initial infection as a result of an inappropriate or inadequate duration of treatment. The stress of multiple manual restraint episodes and challenges with long-term hospitalization and IV catheter maintenance can lead clinicians to discontinue treatment when clinical signs resolve. However, as illustrated by the wallabies of the present report, infection may still be detectable with the use of advanced imaging, well beyond the point of clinical resolution.

Osteolytic lesions, particularly when sequestra are present, often receive subtherapeutic drug concentrations because of poor penetration into the affected area, making it difficult to eliminate infections.⁵,⁶,¹⁷ A few reports exist of successful treatment of mandibular osteomyelitis in macropods, and no standard recommendations exist. Success has been reported for the use of sustained-release chlorhexidine varnish and azithromycin,³ MMA beads impregnated with clindamycin and gentamicin for chronic periapical osteomyelitis,⁵,⁶ parenterally administered gentamicin and penicillin with daily wound flushes,¹ and endodontic filling with apicoectomy.⁶ Radical surgical debridement including dental extractions and mandibulectomy, followed by months of antimicrobial treatment, have also been recommended.⁵,⁹ Use of MMA beads impregnated with antimicrobials can provide higher concentrations of antimicrobials within lesions than those achieved by systemic administration.⁵ However, in the red-necked wallabies of the present report, the beads were difficult to maintain within the lesions while allowing adequate drainage and were not considered beneficial.

Initial treatment of the 2 wallabies included both orally administered and long-acting parenterally administered antimicrobials, which resulted in some improvement but not resolution of disease. Therapeutic choice was initially influenced by safety and ease of administration, ability to maintain the wallaby with the mob, and broad spectrum of activity. In retrospect, more aggressive debridement and treatment targeted at organisms commonly associated with lumpy jaw would be advised at the onset of clinical signs. Although oral clindamycin administration is reportedly effective in treating some kangaroos with lumpy jaw,¹⁸ more aggressive parenteral treatment was chosen for the 2 wallabies because of the progressive osteomyelitis noted on CT scans. A combination of clindamycin and high-dose penicillin was chosen on the basis of culture and susceptibility results and a report² of successful treatment of similar infections in humans with high-dose penicillin.

Intravenous catheter maintenance was somewhat challenging, but the use of long line catheters in the lateral tail vein was beneficial. Subcutaneous injections of penicillin were chosen over IM administration owing to concerns of repeated muscle trauma from daily injections over the extended treatment period. Joeys are not routinely pulled from does to be hand reared, but this may be warranted in certain circumstances. For 1 wallaby of the present report, the joey was removed from the pouch to facilitate more aggressive treatment and prevent potential injury to the joey during repeated handling of the doe. The joey was successfully hand reared and reintroduced to the mob when it was able to self-feed.

Both wallabies of the present report tolerated prolonged hospitalization (293 days and 279 days) for twice-daily manual restraint for drug administration. Intravenous catheters were maintained for 40 and 55 days. Neither wallaby was considered particularly tame at any point, but both tolerated and adjusted to treatment as part of their daily routine. Throughout hospitalization, serial CBC and serum biochemical analyses were performed to monitor organ function and general tolerance of treatment (as reflected by serum creatine kinase or aspartate aminotransferase activity). No important findings associated with repeated handling or ongoing treatment were noted.

From the onset, welfare of the wallabies was considered the greatest priority and weighed into all clinical decisions made. The ability of the wallabies to tolerate treatment was continuously reevaluated to ensure that the best course of treatment was being pursued. Had quality of life appeared diminished or had treatment failed to result in improvement, euthanasia would have been pursued. The effort and resources invested in the treatment of the 2 wallabies was considered worthwhile and in line with the high-quality veterinary care provided to the animal collection of the Brookfield Zoo. However, it is important to discuss the projected cost, time involved, and ability of an animal to tolerate treatment when considering long-term treatment.

Treatment was continued in both wallabies even after radiographic resolution of lesions because of the high incidence of recurrence we have experienced when treatment is stopped prematurely. No recurrence of disease was detected 38 months after treatment concluded.

Compared with conventional radiography, CT imaging offers many diagnostic advantages. It allows avoidance of superimposition of anatomic structures and more thorough evaluation of bony structures to detect subtle changes.¹⁹ Computed tomography is
the diagnostic imaging modality of choice for the evaluation of both soft tissue and bony structures of the head.\(^\text{19}\) Soft tissue or bone detail can be emphasized by use of specific reconstruction algorithms geared toward the individual tissues, and contrast medium administration can be used to further improve soft tissue contrast.\(^\text{19}\) In the 2 red-necked wallabies of the present report, serial CT imaging was considered the most important diagnostic tool that resulted in achieving a beneficial outcome. Even though changes consistent with osteomyelitis can be seen on conventional radiographs, evaluation of changes within the bone can be challenging and recurrent foci of osteomyelitis and sequestrum formation can be missed. Computed tomography provided a more accurate assessment of the mandibular osteomyelitis and informed subsequent decisions to pursue and continue long-term parenteral antimicrobial treatment. Since treatment of the wallabies reported here, CT scans have been incorporated into the Brookfield Zoo’s preventive medicine program for all macropods in an effort to detect early signs of dental disease before osteomyelitis develops and to provide baseline reference images if disease is detected at a later date.

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**Footnotes**

1. ADP-16 Herbivore Diet, Mazuri, Land O’ Lakes Inc, Saint Paul, Minn.
2. Precedex, Pfizer, New York, NY.
5. Metacam, Boehringer Ingelheim Vetmedica, St Joseph, Mo.
7. West-Ward Pharmaceuticals Corp, Eatontown, NJ.
8. WG Critical Care, Paramus, NJ.
9. Intervet Inc, Summit, NJ.
11. Hospira Inc, Lake Forest, Ill.
14. Vetrap, 3M Animal Care Products, Saint Paul, Minn.
15. HiSpeed CT/I, GE Medical Systems, Waukesha, Wis.
16. GE Healthcare Ireland, Cork, Ireland.
17. Hi-Tech Pharmaceuticals, Amityville, NY.
18. Amneal Pharmaceuticals, Hauppauge, NY.
20. Dynarex, Orangebug, NY.

**References**