

Prevalence, distribution, and progression of radiographic abnormalities in the lungs of cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*): 89 cases (2002–2005)

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Objective—To evaluate the prevalence, distribution, and progression of radiographic abnormalities in the lungs of cold-stunned Kemp's ridley sea turtles (*Lepidochelys kempii*) and associations between these abnormalities and body weight, carapace length, and hematologic and plasma biochemical variables.

Design—Retrospective case series.

Animals—89 cold-stunned juvenile Kemp's ridley sea turtles.

Procedures—Medical records were reviewed. Dorsoventral and horizontal beam craniocaudal radiographs were evaluated for the presence, distribution, and progression of lung abnormalities. Turtles were categorized as having radiographically normal or abnormal lungs; those with abnormalities detected were further categorized according to the distribution of abnormalities (left lung, right lung, or both affected). Body weight, carapace length, and hematologic and plasma biochemical data were compared among categories.

Results—48 of 89 (54%) turtles had radiographic abnormalities of the lungs. Unilateral abnormalities of the right or left lung were detected in 14 (16%) and 2 (2%), respectively; both lungs were affected in 32 (36%). Prevalence of unilateral abnormalities was significantly greater for the right lung than for the left lung. Evaluation of follow-up radiographs indicated clinical improvement over time for most (18/31 [58%]) turtles. Prevalence of bilateral radiographic abnormalities was positively correlated with body weight and carapace length. There was no significant association between radiographic category and hematologic or plasma biochemical variables.

Conclusions and Clinical Relevance—Radiographic abnormalities of the lungs were commonly detected in cold-stunned Kemp's ridley turtles. Results of this study may aid clinicians in developing effective diagnostic and treatment plans for these patients. (*J Am Vet Med Assoc* 2013;242:675–681)

Kemp's ridley turtles (*Lepidochelys kempii*) are an endangered sea turtle species found in waters of the southern United States and Mexico. Juveniles of this species are known to seasonally inhabit waters as far north as New England.¹ In autumn, juvenile Kemp's ridley turtles may become debilitated in the northwestern Atlantic ocean as water temperatures rapidly decrease and animals are forced to shore by prevailing winter weather patterns.^{2,3} These animals are susceptible to severe hypothermia, a condition referred to as cold stunning.³ Cold-stunned Kemp's ridley turtles

are often found stranded along beaches of Cape Cod, Mass, from November to late December.^{1,4,5} Common medical disorders of cold-stunned sea turtles include dehydration, metabolic disturbances, and pathological conditions of the digestive, neurologic, and respiratory systems, including pneumonia.^{5–7} A recent retrospective study⁶ of necropsy and histopathologic findings in cold-stunned Kemp's ridley turtles documented pathological changes of the lungs, primarily pneumonia, in 57% of cases.

Radiography is commonly used for evaluation of the reptilian respiratory tract^{8,9}; however, most reports of its use are limited to clinical reports^{10,11} of individual animals. No previous reports have been published that describe in detail the radiographic anatomy of the lungs of sea turtles. The general radiographic anatomy of loggerhead turtles (*Caretta caretta*) has been described, but only a brief mention of the radiographic appearance of the pulmonary parenchyma and pulmonary vessels is available.¹²

The purpose of the study reported here was to retrospectively evaluate the prevalence, distribution, and progression of radiographic abnormalities in the

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lungs of cold-stunned Kemp's ridley sea turtles. We also investigated correlations between these abnormalities and body weight, carapace length, and hematologic and plasma biochemical data.

Materials and Methods

Sea turtle rehabilitation at the New England Aquarium was conducted with authorization of the US Department of the Interior Fish and Wildlife Service and the US Department of Commerce National Marine Fisheries Service, in compliance with guidelines of the New England Aquarium Animal Care and Use Committee.

Criteria for selection of cases—Medical records of live cold-stunned Kemp's ridley turtles admitted to New England Aquarium between November 1, 2002, and December 31, 2005, were reviewed retrospectively. Turtles were included in the study if initial radiographs were obtained ≤ 48 hours after admission to the hospital and no traumatic injuries were evident. The first and last radiographs obtained during hospitalization were evaluated by a board-certified veterinary radiologist (MS) for the presence of radiographic abnormalities of the lungs. Other data collected included radiography dates; body weight, carapace length (determined for the live turtle by use of calipers along the dorsal midline from the nuchal scute to the notch at the junction of the last marginal scutes), and results of a CBC and plasma biochemical analysis obtained during the first 5 days of hospitalization; and whether turtles survived to discharge. For turtles with radiographic abnormalities detected in the lungs, medical records were evaluated to determine whether antimicrobial treatment was administered. Seventy-four of the turtles evaluated in this study were previously included in a retrospective study⁷ of hematologic and plasma biochemical data of cold-stunned turtles.

Radiography and evaluation of images—A standardized method of radiography was used during the 5-year study period, including dorsoventral and horizontal beam craniocaudal full-body views obtained via a veterinary radiographic system^a with x-ray cassettes^b and regular-speed film^c at a focal distance of 1 m. Exposure factors varied with the size of the patient; however, typical exposure factors were 65 kVp, 25 mA, and 0.25 seconds for the craniocaudal projection. To avoid motion and superimposition of the head and limbs in these images, turtles were placed on a pedestal, which resulted in the head and limbs relaxing ventral to the carapace. Typical exposure factors for the dorsoventral projection were 62 kVp, 15 mA, and 0.65 seconds.

The radiologist was blinded to the clinical history of each turtle. Turtles were categorized as having radiographically normal or abnormal lungs via examination of initial radiographs. Assessment of normal radiographic anatomy of the lungs was based on the clinical experience of the authors, in the absence of reported normal radiographic anatomy for this species. In addition, radiographs of 5 healthy Kemp's ridley turtles unrelated to the study population were reviewed to help determine the normal radiographic appearance of the lungs.

Turtles with radiographic abnormalities of the lungs were further categorized according to the location of those abnormalities (left, right, or both lungs).

Pronounced asymmetry in the size of lung fields was interpreted as a sign of pulmonary disease, unless it was clearly caused by distension of the adjacent gastrointestinal tract. Reduction of lung field size was considered abnormal only when the affected lung was subjectively smaller by greater than one-third of the contralateral lung field and concurrent irregularities of the lung borders were detected on the dorsoventral projection.

For turtles initially categorized as having radiographic abnormalities of the lungs and for which follow-up radiographs were available, the number of days between initial and final radiographs was determined. Initial radiographs were compared with final radiographs to assess changes over time. Abnormalities were subjectively categorized as improved, worsened, or unchanged in follow-up radiographs relative to findings for initial radiographs.

Other variables—Straight carapace length, body weight, and results of hematologic (WBC and differential [heterophil, lymphocyte, and monocyte] counts and Hct) and plasma biochemical analysis (alkaline phosphatase, aspartate aminotransferase, creatine kinase, and lactate dehydrogenase activities and concentrations of albumin, total protein, globulin, BUN, glucose, calcium, phosphorus, chloride, potassium, sodium, and uric acid) were compared among turtles that survived to discharge; turtles were grouped according to radiographic categorization of the lungs (normal, unilateral abnormalities, or bilateral abnormalities). Methods used for hematologic and plasma biochemical analysis for these turtles have been described.⁷

Statistical analysis—The prevalence of unilateral abnormalities of the left and right lungs was compared via estimation of binomial parameters by use of statistical software,^d with a null hypothesis of an equal number of cases in each category ($P < 0.05$). Hematologic, biochemical, and morphometric data were tested for normality (Shapiro-Wilk test), and if normally distributed, each variable was compared among radiographic categories via 1-way ANOVA. For variables that failed the test of normality, data were examined via Kruskal-Wallis 1-way ANOVA on ranks. Significant differences were further assessed with the Dunn method for multiple pairwise comparisons. For variables that were significantly different among groups via the Kruskal-Wallis ranking method, the true value and not the ranked result was reported. Analysis was conducted with statistical software.^e Values of $P < 0.05$ were considered significant.

Results

Records for 89 Kemp's ridley turtles met criteria for inclusion in the study. Mean \pm SD carapace length was 27 ± 3.5 cm, and body weight was 2.9 ± 1.0 kg (6.38 ± 2.2 lb). Age and sex could not be determined externally for these immature turtles. Seventy-nine turtles were successfully rehabilitated and released to the wild.

Forty-one (46%) turtles in the study were categorized as having radiographically normal lungs, with abnormalities detected bilaterally or unilaterally in the remaining 48 (54%) turtles (Figures 1–3). Both lungs were affected in 32 (36%) turtles; 14 (16%) and 2 (2%) had only the right or left lung affected, respectively.

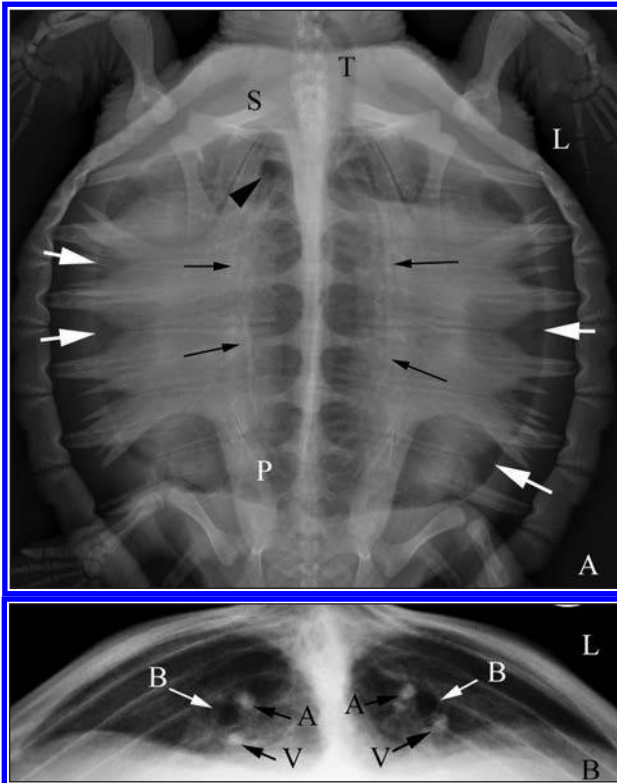


Figure 1—Dorsoventral (A) and horizontal beam craniocaudal (B) radiographic projections of a cold-stunned Kemp's ridley sea turtle (*Lepidochelys kempii*) categorized as having normal lungs. On the dorsoventral view, notice the right bronchus as it enters the lung (black arrowhead), lateral margins of the lungs (white arrows), and the pulmonary vasculature (black arrows). On the craniocaudal view, notice the orientation of the bronchi, pulmonary arteries, and pulmonary veins. A = Pulmonary artery. B = Bronchus. L = Left. P = Lateral pubic process. S = Scapula. T = Trachea. V = Pulmonary vein.

Ten turtles did not survive to discharge from the hospital; 5 of these were categorized as having radiographically normal lungs, 1 had radiographic abnormalities of the right lung, and 4 had bilateral abnormalities. Of the surviving 79 turtles, 36 (46%) were categorized as having normal lungs; 2 (3%), 13 (16%), and 28 (35%) had radiographic abnormalities of the left, right, or both lungs, respectively.

The typical radiographic appearance of lungs in clinically normal Kemp's ridley turtles of this study included the following features: on the dorsoventral projection, the lungs were characterized by symmetrically aerated, radiolucent fields. Minor differences in size between the left and the right lungs were seen. The lateral borders of the lung fields conformed loosely to the shape of the carapace, so that each lung was wider at its cranial third and narrower at its caudal third. Both the cranial and caudal borders of the lung fields terminated abruptly, resulting in a somewhat convex soft tissue–air interface that could be easily recognized on the dorsoventral projection. Minor asymmetry in the borders of the lungs, especially at the most caudal lateral aspect of the lung lobes, was present. The lungs occupied approximately three-quarters to four-fifths of the width of the coelomic cavity (lateral edge to lateral edge) on the dorsoventral projection. They reached the level of the

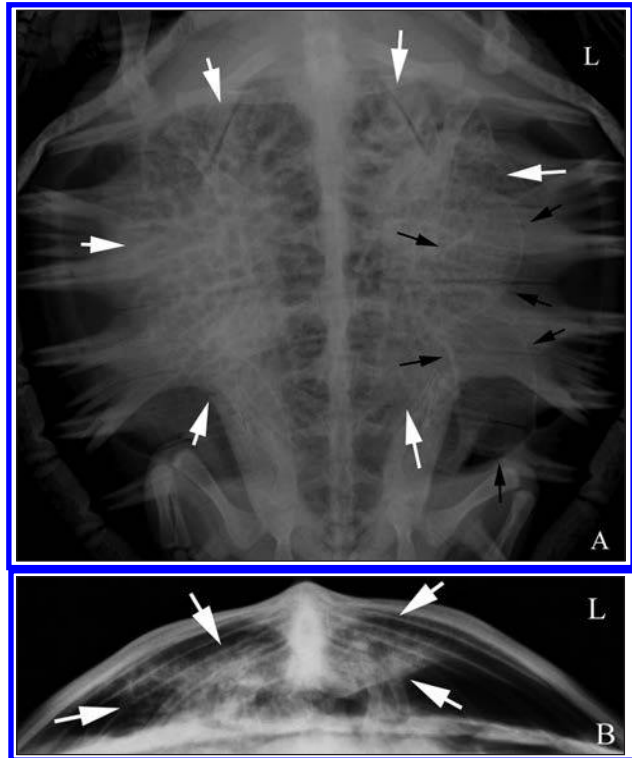


Figure 2—Dorsoventral (A) and horizontal beam craniocaudal (B) radiographic projections of a cold-stunned Kemp's ridley sea turtle categorized as having bilateral lung disease with a reticular (honeycomb) pattern (white arrows). This pattern is characterized by multiple irregularly shaped lucencies with thick borders. There are 2 gas-filled bowel loops in the left lateral aspect of the coelom on the dorsoventral view (black arrows). L = Left.

scapula and acromion process cranially during inspiration. Caudally, they reached the midbody of the pubis.

Unlike findings reported in loggerhead turtles,¹² the pulmonary vessels were not superimposed on each other on the dorsoventral view and were clearly visible as 2 distinct parallel structures. Secondary blood vessels could be seen branching off of the primary vessels despite a superimposed prominent stellate pattern of the plastron bones. However, because of the smaller size and more delicate pulmonary parenchyma of the lungs in Kemp's ridley turtles, the secondary pulmonary vessels were less identifiable than in loggerhead turtles. The trachea was clearly visible in most turtles and was located to the left of the midline in the cervical area in the dorsoventral projection. However, its bifurcation was not always clearly seen because of the overlying cervical vertebrae. The most cranial extent of the left primary bronchus was generally seen in an end-on orientation in the dorsoventral projection, whereas the right bronchus was seen in a left-to-right orientation and was often detected in an end-on orientation close to the point where it entered the right lung.

In the horizontal beam craniocaudal projections (Figure 1), the dorsal borders of the lungs were not visible because they were located immediately ventral to the carapace. The most ventral and lateral aspects of the parietal surface of the lungs were discerned in this projection where the lungs curve medially and away from the carapace. In most turtles, the main bronchi and adjacent pulmonary vessels were visible in an end-

on orientation. Each primary bronchus was clearly seen between the associated pulmonary artery and vein. In these projections, aerated lungs in healthy turtles occupied up to approximately 50% of the dorsoventral dimension in radiographs obtained at the peak of inspiration. Variations in the amount of gastrointestinal tract contents caused asymmetry in the degree of lung aeration. Changes in lung size varied according to the respiratory cycle, although most images generally revealed well-insufflated lungs due to the typical inspiratory breath-holding respiratory pattern of sea turtles. Pulmonary parenchymal markings were more prominent on craniocaudal projections than on orthogonal dorsoventral projections (possibly because the x-ray beam penetrated a greater thickness of parenchyma).

The prevalence of unilateral radiographic abnormalities was significantly ($P = 0.013$) greater for the right lung than the left lung (14/89 [16%] vs 2/89 [2%], respectively). Among turtles with bilateral lung abnormalities, lesions frequently appeared to be more severe in the right lung (10/32), compared with the left (1/32), although this was not evaluated statistically.

Pulmonary changes were subjectively generally easier to detect on the dorsoventral view than the craniocaudal

view because there was greater superimposition of the carapace, pectoral, and pelvic girdles on the lung fields in the craniocaudal view. Abnormalities found on radiographs varied from focal to multifocal to generalized increased interstitial patterns. As with domestic terrestrial species, clarity of the pulmonary vessels in radiographic images was used to ascertain the presence of pulmonary infiltrates. Changes varied from patchy areas of well-defined edicular infiltrates obscuring the pulmonary vasculature to more diffuse generalized interstitial patterns (Figure 4). No evidence of well-defined pulmonary nodules was found in any of the radiographs evaluated. A reticular, honeycomb pattern was detected in 11 turtles (Figure 2). This pattern was characterized by multiple irregularly shaped lucencies in close apposition to each other that partially obscured the pulmonary vessels.

Follow-up radiographs were available for 31 turtles and were obtained a mean of 75 days after initial radiographs (median, 38 days; range, 2 to 291 days). Abnormalities were categorized as improved in 18 (58%; Figure 5), worsened in 6 (19%), and unchanged in 7 (23%) turtles. Radiographs in which abnormalities were categorized as improved were obtained a mean of 72 days after initial radiographs (median, 45 days; range, 2 to 291 days). Those in which abnormalities were categorized as worsened were obtained a mean of 34 days after initial radiographs (median, 27 days; range, 15 to 73 days). Radiographs in which abnormalities were unchanged were obtained a mean of 52 days after initial radiographs (median, 53 days; range, 8 to 106 days). All of the turtles for which follow-up radiographs were available were later released.

None of the tested hematologic and plasma biochemical variables (data not shown) varied significantly (1-way ANOVA [$P > 0.31$] or Kruskal-Wallis 1-way ANOVA on ranks [$P > 0.11$]) with radiographic category. Body weight and carapace length were significantly (Kruskal-Wallis 1-way ANOVA on ranks; $P < 0.028$ and $P < 0.04$, respectively) correlated with radiographic category. Turtles with bilateral radiographic abnormalities were heaviest and longest (mean weight, 3.27 kg [7.2 lb]; mean length, 28.2 cm), and those with radiographically normal lungs (mean weight, 2.66 kg [5.9 lb]; mean length, 26.2 cm) were lightest and shortest. Weights and lengths differed significantly (Dunn multiple comparison method) between these

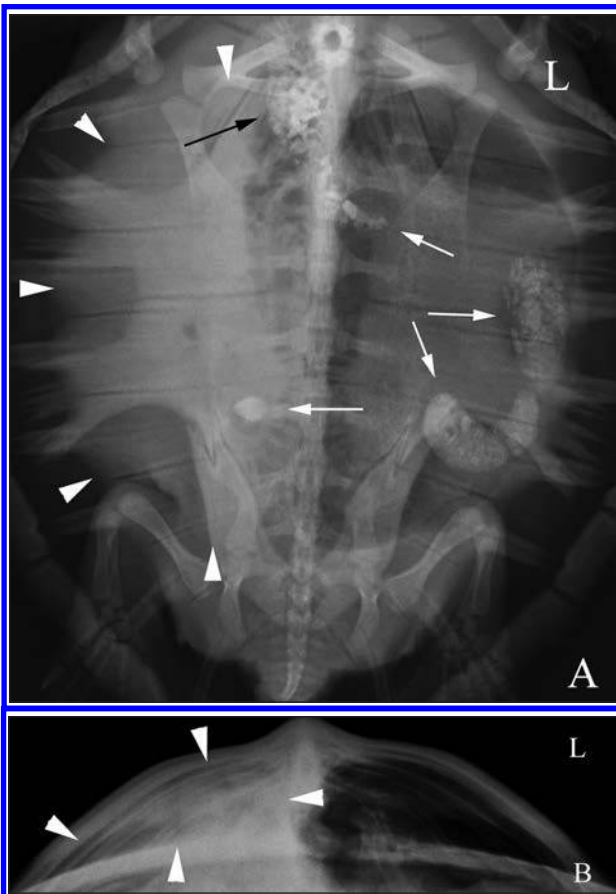


Figure 3—Dorsoventral (A) and horizontal beam craniocaudal (B) radiographic projections of a cold-stunned Kemp's ridley sea turtle classified as having unilateral abnormality of the right lung, which was confirmed as granulomatous bacterial pneumonia via necropsy and histologic evaluation. There is diffuse severely increased radiopacity of the right lung (white arrowheads). Notice mineralized ingesta in the digestive tract (white arrows) and kera-tinized esophageal papillae (black arrow). L = Left.

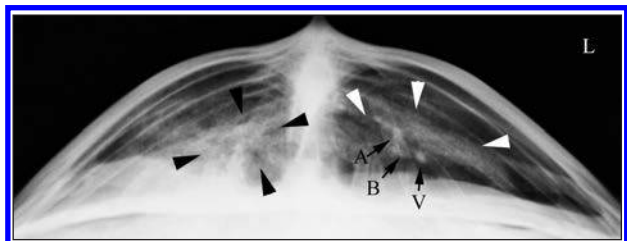


Figure 4—Horizontal beam craniocaudal radiographic projection of a cold-stunned Kemp's ridley sea turtle classified as having bilateral lung abnormalities. There is asymmetric reduction in lung volume, and patterns differ between the right and left lungs. Right lung changes are characterized by patchy areas of well-defined edicular infiltrates obscuring the pulmonary vasculature with reduction of lung volume (black arrowheads), and left lung changes are characterized by a more diffuse generalized interstitial pattern (white arrowheads) resulting in poorly defined but detectable pulmonary vasculature. See Figure 1 for remainder of key.

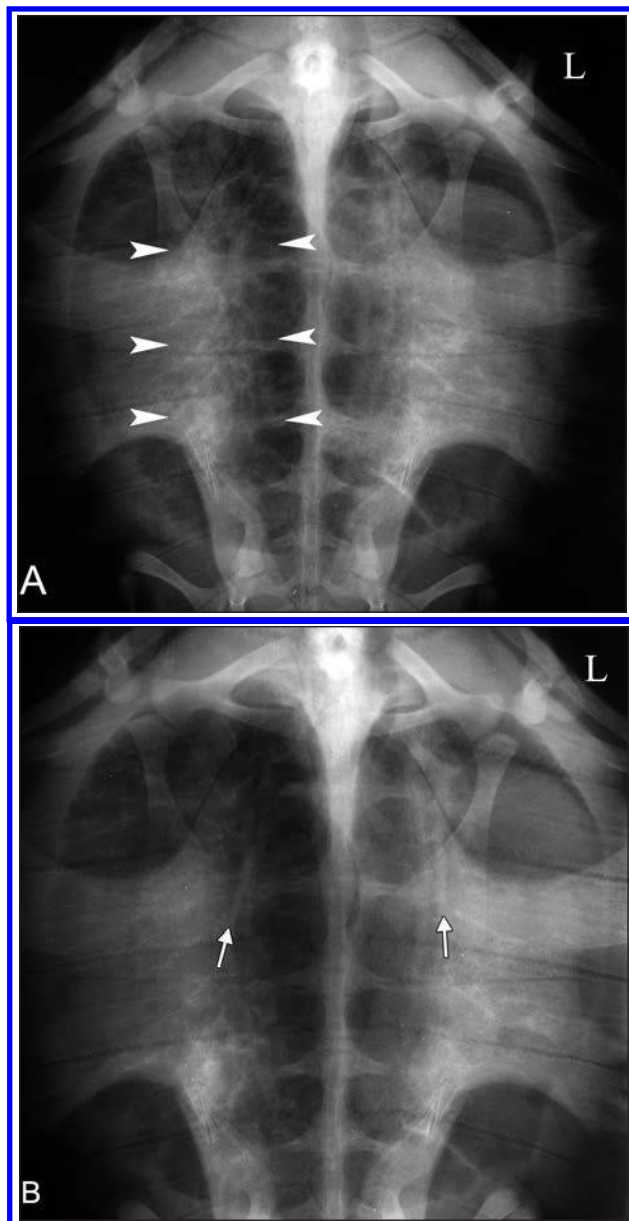


Figure 5—Initial (A) and follow-up (B) dorsoventral radiographs of a cold-stunned Kemp's ridley sea turtle with a 45-day interval between imaging dates. In panel A, bilaterally increased pulmonary opacity partially obscures the pulmonary vasculature. The markings have a reticular (honeycomb) pattern (arrowheads) and are seen along the entire length of the medial half of each lung. In panel B, the pattern has decreased in severity after 45 days, and the pulmonary vasculature is better defined (arrows). Although improved, radiographic abnormalities are still present; notice persistent opacities in the caudal third of both lungs.

groups, but neither was significantly different from that of turtles with unilateral radiographic abnormalities (mean weight, 2.87 kg [6.3 lb]; mean length, 26.7 cm). Antimicrobial treatment had been administered to all turtles categorized as having radiographic abnormalities of the lungs.

Discussion

Dorsoventral and horizontal beam craniocaudal radiographs revealed a high prevalence of radiograph-

ic abnormalities of the lungs in cold-stunned Kemp's ridley turtles. The prevalence of lung abnormalities in the present study was similar to that found in a retrospective study⁶ of necropsy records for cold-stunned turtles from the same population; however, a significantly greater prevalence of unilateral abnormalities of the right lung, compared with the left, was not found in that study, possibly because the number of turtles was small ($n = 28$).

On the basis of reports^{6,13–16} describing postmortem evaluations, pneumonia is the most common cause of pulmonary disease in Kemp's ridley turtles and is often associated with opportunistic bacterial and fungal infections. Thus, the radiographic abnormalities seen in the present study were most likely attributable to pneumonia. However, because of the low number of deaths and limited or incomplete postmortem data for these turtles, we cannot definitively state that the findings were indicative of pneumonia. Parasitic disease may be a cause of pneumonia in sea turtles in some regions, but this was not commonly found in turtles from the same population at necropsy.⁶ As such, fecal parasite examination was not routinely performed for turtles of the study reported here. Detailed review of medical records for cytologic or microbiological evidence of pneumonia was beyond the scope of the study.

The most striking abnormal radiographic finding was the presence of an enhanced reticular (honeycomb) pattern in 11 turtles. This pattern corresponds well to the large trabeculae and small alveolus-like ediculae of sea turtle lungs.^{17,18} The main radiographic finding that was used to assess the lung parenchyma in turtles of the present study was definition of the borders of the pulmonary vasculature on the dorsoventral projection. Turtles that were considered to have radiographic abnormalities of the lungs had poorly defined pulmonary vessels, which were partially obscured by the presence of the well-defined enhanced reticular pattern. This pattern also resulted in asymmetric increased soft tissue opacity of the affected lung that was clearly discerned over the relatively homogenous soft tissue opacity of the coelomic viscera. Other less consistent abnormal radiographic findings included a pronounced asymmetry between lung lobes and the presence of severely irregular pleural borders with indentations in lung parenchyma. It is unknown whether these asymmetric indentations are normal anatomic variations or the result of previous lung lobe injury such as fibrosis. In some turtles, the affected lung lobe tended to be smaller and more irregular than the contralateral unaffected lung lobe. Reduction in the size of the lungs was a subjective assessment because normal slight asymmetry between lungs can be seen in clinically normal animals. It is unknown whether the reticular pattern represents emphysematous lesions, edicular thickening, bronchial wall thickening, or patchy infiltrates between partially aerated lung fields. We speculate that it may result from a combination of edicular wall and terminal airway thickening and that irregular lung borders represent pleural thickening. Pleural disease has been described in cold-stunned Kemp's ridley sea turtles.⁶

Follow-up radiographs were not available for most turtles of this study because many were transferred to

other institutions or died after having only initial radiographs. Of the 31 patients for which follow-up radiographs were available, most (18 [58%]) had resolution of lung abnormalities over time, but several (13) did not have detectable improvement in the last available radiograph, compared with the first. The described reticular pattern resolved in most (7/11) affected turtles. In turtles in which these changes were resolving, pulmonary vessels became more clearly defined, and the affected lung increased in size and had a more radiolucent pulmonary parenchyma. In some turtles, the pulmonary borders were less irregular in follow-up images.

The mean interval between initial and follow-up radiographs was greatest for turtles with radiographic improvement (72 days), compared with those in which the findings were unchanged or worsened over time (52 and 34 days, respectively). It is possible that this reflected a prolonged process of resolution and suggests that follow-up radiographs for this species should be obtained over several months to assess resolution of these signs. Given that all 31 of the turtles that had follow-up radiographs were later released, clinicians sometimes judged that turtles were completely clinically stable and could be safely released in the absence of final radiographs demonstrating complete resolution of lung abnormalities. Although this may have been clinically reasonable, additional studies should be conducted to determine criteria for assessing pulmonary radiographs in this species. For example, a prospective study comparing radiographic findings with bronchoscopic, tomographic, microbiological, and histopathologic findings would be useful to confirm the diagnosis of pneumonia and to differentiate chronic pneumonia from fibrotic changes on convalescent radiographs. In addition, data collected in the study reported here did not allow for correlation of specific pulmonary radiographic patterns with specific pathological changes or outcomes because of the limited numbers of radiographs that revealed particular patterns, variable gradations of patterns, and the generally high survival rate (79/89 [89%]) of these patients. It is possible that evaluation of a larger number of cases could allow for such correlations to be made in future studies.

Turtles with bilateral radiographic abnormalities of the lungs were significantly heavier and longer (mean weight, 3.27 kg; mean length, 28.2 cm) than those with radiographically normal lungs (mean weight, 2.66 kg; mean length, 26.2 cm). The reasons for this finding are not clear, but the weight difference may have been attributable to the heavier pulmonary parenchyma or presence of aspirated sea water in turtles with bilateral pathological changes. Larger cold-stunned sea turtles could also be more likely to aspirate sea water during stranding because they may float lower and are less buoyant, which may lead to a more generalized disease. It is also possible that larger turtles are more likely to aspirate larger volumes of water during stranding as a result of the larger diameter of the trachea. Differentiating between these possibilities and others was not possible on the basis of the data collected.

Although speculative, the higher prevalence of unilateral radiographic abnormalities of the right lung, compared with the left (14/89 [16%] vs 2/89 [2%], re-

spectively), may suggest that pneumonia in Kemp's ridley turtles developed secondary to aspiration of sea water during the stranding event. On the basis of necropsy, bronchoscopy, and CT findings (unpublished data), the entrance to the right main bronchus in this species is located ventral to the entrance to the left main bronchus at the tracheal bifurcation; therefore, it could more easily accumulate sea water and debris during aspiration, and pneumonia may be more likely to develop or may be more severe in the right lung. Additional diagnostic modalities, such as pulmonary ventilation (aerosol) scintigraphy or mucociliary clearance scintigraphy,¹⁹ could be useful in testing this hypothesis.

In the present study, approximately half of survivors and nonsurvivors had normal pulmonary radiographic findings. Thus, there did not appear to be a correlation between survival rate and the presence or absence or distribution of radiographic lung abnormalities, although this was not evaluated statistically. Similarly, there was no correlation of hematologic and plasma biochemical variables with the presence or absence or distribution of these abnormalities. Results of other studies⁷ have revealed hematologic and plasma biochemical abnormalities in cold-stunned Kemp's ridley sea turtles and have shown that such data may have prognostic value. On the basis of results of the present study, such changes are not sensitive or specific indicators of lung disease. This is most likely because a wide variety of metabolic and hematologic derangements develop in cold-stunned turtles in general, regardless of the presence of pulmonary abnormalities. For example, turtles with or without pulmonary abnormalities could be affected by dehydration, reduced renal function, poor tissue perfusion, or sepsis. Detecting the influence of pulmonary disease on initial hematologic and plasma biochemical variables in turtles of the present study was thus likely masked by other concurrent abnormalities.

All turtles with radiographic abnormalities of the lungs were treated with antimicrobial agents, often including both systemic antimicrobials and antifungal drugs. However, detailed review of specific medical treatments for each turtle was beyond the scope of this study. Medical management was determined by a number of veterinarians during the years included in this study and was not consistent among all turtles. Often because of temporal, financial, and personnel constraints, initial empirical treatment was selected after review of radiographs, without obtaining a specific diagnosis of pneumonia via bronchoscopy, tracheal wash, or other methods. In some cases, treatment plans were later modified on the basis of specific diagnostic test results and response to treatment. It is recognized that it would have been preferred to obtain such information prior to starting antimicrobial treatment.

Identification of pulmonary vasculature in this study was based on gross dissection and radiographic and CT studies^{12,20,21} in loggerhead turtles. Similar to the cranio-caudal view of loggerhead turtles, the cranio-caudal view in Kemp's ridley turtles showed that each pulmonary artery is dorsal to the associated bronchus, whereas each pulmonary vein is ventral to the bronchus. In the dorsoventral view, the anatomic location of the pulmonary artery versus the pulmonary vein has

not been clearly described, and they have been generally referred to as pulmonary vessels in loggerhead turtles because they are superimposed on each other.¹² Additional gross anatomic and postmortem radiographic studies are needed to clarify the radiographic anatomy of the pulmonary vessels on the dorsoventral projection in Kemp's ridley turtles, in which the artery and vein are not superimposed. Studies of the vasculature involving use of contrast enhancement techniques may also be useful in clarifying this point.

Although radiographic exposure techniques can change the appearance and degree of opacity of the lungs, most detected patterns were well-defined and clearly different from the normal parenchyma, especially when the changes included edicular infiltrates or the reticular pattern. Similar to evaluations in domestic animals, when a mild diffuse interstitial pattern is present and the exposure techniques are suboptimal, one must be careful not to overinterpret the radiographic changes.

In addition to respiration, the lungs of sea turtles are important in the maintenance of normal buoyancy and diving ability.¹⁷ Maximal lung volume in loggerhead sea turtles and green sea turtles (*Chelonia mydas*) has been shown to range from 6% to 11% of their body weight, similar to the lung volume recorded in other reptiles.¹⁷ Pulmonary disease can have a substantial effect on maintenance of buoyancy and diving capabilities.¹³ Cold-stunned turtles often develop buoyancy abnormalities and may list to 1 side if asymmetric pulmonary disease is present.^{2,5}

Although other imaging modalities, such as CT, provide greater anatomic detail of the lungs in sea turtles because of the lack of superimposition of the carapace,²⁰ radiography is a less expensive and readily available modality. Localization of pulmonary abnormalities via radiography allows more targeted sample collection and treatment of focal lesions via bronchoscopy, needle aspiration, lung biopsy, and intrapulmonary treatment.¹⁰ The high prevalence of pulmonary radiographic abnormalities in the study reported here indicates that serial radiography should be routinely included in the medical evaluation of cold-stunned sea turtles.

- Innovet Select 20-kHz system, Summit Industries, Chicago, Ill.
- Econosette Rarex Green Regular cassettes, MCI Optonix, Cedar Knolls, NJ.
- ClinicSelect Regular Speed Green film, Eastman Kodak, Rochester, NY.
- StatXact, version 8.0, Cytel Software Corp, Cambridge, Mass.
- SigmaPlot, version 12, SigmaPlot Software Inc, San Jose, Calif.

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