

Brief communication (original)

Open access

Cardiac involvement in children with community-acquired pneumonia and respiratory failure

Kachaporn Nimdet^{1,*}, Win Techakehakij²

Abstract

Background: Pneumonia causes significant incidence in children younger than 5 years. Most fatalities are resulted from complications. High rates of cardiac events were detected in adult studies but usually related to underlying diseases.

Objective: To study the cardiac effects of community-acquired pneumonia (CAP) with respiratory failure (RF) in healthy children.

Methods: The prospective cohort study was conducted in children aged 2–59 months with CAP and RF. Cardiac enzyme assessments, chest radiography, electrocardiography, and echocardiography were performed at the admission date and 2 weeks after admission. t-test and chi-square test were used for comparison between first and second investigations, and the statistically significance level was a $P < 0.05$.

Results: Of the 135 patients, pericardial effusion occurred in 80 (59%), valvular regurgitation in 30 (22%), ST/T changes in 66 (49%), cardiac arrhythmia in 7 (5%), and myocardial injury in 83 (62%). Significant improvement of cardiothoracic-ratio, heart rate, ST/T changes, cardiac arrhythmia, troponin T, myocardial performance, and left-ventricular ejection fraction was demonstrated at second investigations. Three mortality cases exhibited evidence of congestive heart failure (CHF).

Conclusion: Children with CAP and RF had several cardiac effects even in healthy children. Most cardiac effects were mild and transient. Mortality cases were revealed evidence of congestive heart failure (CHF). Future research should be designed to find out the characteristics and predictors of CHF for early recognition and therapeutic strategy.

Keywords: cardiac effects; myocardial injury; pericardial effusion pneumonia; respiratory failure


Pneumonia remains an important disease, causing significant incidence and mortality in developing countries around the world. The incidence is 61 million cases in the South East Asia region [1] and 156 million cases worldwide [2] with an estimated 0.9–1.2 million deaths per year in children younger than 5 years [3, 4]. Mortality cases in children might have resulted

from complications such as persistent pneumonia, acute respiratory distress syndrome (ARDS), sepsis, parapneumonic effusion, and pericardial effusion [5]. In adult studies, there were high rates of cardiac complications such as heart failure, arrhythmia, and acute coronary syndrome with the result of increasing morbidity and mortality [6, 7].

*Correspondence to: Kachaporn Nimdet, Department of Pediatrics, Suratthani Hospital, Suratthani 84000, Thailand, e-mail: kachaporn.ni@cpird.in.th

¹Department of Pediatrics, Suratthani Hospital, Suratthani 84000, Thailand

²Department of Social Medicine, Lampang Hospital, Lampang 52000, Thailand

Open Access. © 2020 Nimdet and Techakehakij, published by Sciendo.  This work is licensed under the Creative Commons Attribution NonCommercial-NoDerivatives 4.0 License.

High rates of cardiac events in adults were associated with chronic underlying diseases such as coronary artery disease, renal failure, and hypertension. To exclude risk factors, this study focused on healthy children with severe community-acquired pneumonia who developed respiratory failure (RF) as most cases of morbidity and mortality of pneumonia were occurred in these conditions to find out the exactly cardiac involvement in pediatric groups.

Patients and methods

Study design

The prospective cohort study was an observational study conducted between June 2011 and June 2014 in the Pediatric Department of Suratthani Hospital, Thailand. The study was approved by the Independent Ethical Committee of Suratthani Hospital, Thailand (Ref. No. 18/2011, 41/2012, 23/2013, and 17/2014). Written informed consent was obtained from the parents or legal guardians of each patient.

Study selection

The inclusion criteria included children aged 2-59 months who had been admitted with diagnoses of pneumonia with RF. CAP with RF was defined as follows: (1) acute lower respiratory tract infection acquired in a community of healthy children [8]; (2) the need for intubation due to an increase in respiratory rate with signs of distress or an inadequate respiratory rate, particularly when accompanied by depressed mental status and cyanosis despite oxygen supplementation [9]; and (3) the presence of radiologic evidence of infiltrates on chest radiography [10].

The exclusion criteria were as follows: (1) patients with underlying diseases, such as congenital heart disease (CHD), congestive heart failure (CHF), bronchopulmonary dysplasia, chronic lung disease, renal insufficiency, cerebral palsy and neurological disease and (2) patients with previous hospitalizations within 1 month.

Study protocol

All patients who met the inclusion and exclusion criteria had histories and baseline characteristics reported. Blood samples were obtained at the time of admission for hemocultures, complete blood counts, assessments of blood urea nitrogen,

creatinine, electrolytes, troponin T, and liver function tests. Tracheal aspiration samples were obtained for bacterial culture and viral study with a polymerase chain reaction. Chest radiography (CXR), electrocardiography (ECG), and echocardiography were performed upon admission.

Two weeks after admission, blood samples were collected for troponin T assessments, and CXR, ECG, and echocardiography were performed. Additional investigations were performed outside of this schedule in cases that exhibited symptoms that were clinical compatibility with cardiac events, such as CHF, arrhythmia, hemodynamic instability or sepsis, during hospitalization.

After discharge from the hospital, the patients with abnormal laboratory results or persistent clinical symptoms were followed up every 2 weeks until their conditions normalized.

Definitions of variables

Myocardial injury was defined as a troponin T value greater than 0.014 ng/mL [11, 12]. Valvular regurgitation was defined by the echocardiographic demonstration of valvular regurgitation on the first echocardiogram and the disappearance of this condition at the follow-up or a decrease in the severity of regurgitation over by that time. Trivial tricuspid regurgitation was not included because this condition can be observed in normal structures in normal physiological conditions [13]. Pericardial effusion was defined as the presentation of pericardial effusion in the diastolic phase on the echocardiogram. Small effusion was defined as an effusion of less than 2 mm, effusions of 2-10 mm were defined as moderate, and effusions greater than 10 mm were defined as large [14]. ST/T changes were determined by the elevation or depression of the ST segment and the presence of an inverted or upright T-wave that was not compatible with normal findings for the age groups [15].

Left ventricular ejection fraction (LVEF) was assessed by using M-mode. The Tei index of myocardial performance (IMP) was used to evaluate the combination of systolic and diastolic ventricular functions. An impairment of IMP refers to the value is greater than 0.24 ± 0.04 for the right ventricular index of myocardial performance (RVIMP) and 0.40 ± 0.09 for children aged 3-18 years and 0.33 ± 0.02 for children aged <3 years for the left ventricular index of myocardial performance (LVIMP) [16]. CHF was defined in the patients who developed clinical signs and symptoms of CHF, such as tachypnea, hepatomegaly, S3 gallop, or cardiogenic shock with radiological findings of cardiomegaly and pulmonary congestion [17], after admission.

Statistical analysis

Statistical calculations were performed using Stata version 13 [18]. Continuous data are expressed as the mean \pm SD. Nominal data were reported as number and percentage. T-test was used to compare between first and second results of continuous variables i.e. troponin T, heart rate, cardiothoracic ratio of CXR, and echocardiographic parameters. The T-test is also used to compare the length of hospital stay between present cardiac-involvement and absent cardiac-involvement patients. The comparison between the incidence of cardiac arrhythmia, pericardial effusion, valvular regurgitation, and myocardial injury was evaluated by Chi-square test. Two-sided $P < 0.05$ were considered statistically significant.

Results

A total of 139 patients were included in this study. After investigations, four patients were excluded. An acute asthmatic patient had no evidence of pulmonary infiltrates on CXR. Three CHD patients in this admission were diagnosed by echocardiographic examination. The cardiac defects were double aortic arch with ventricular septal defect, patent ductus arteriosus, and perimembranous type-ventricular septal defect. Of the remaining 135 patients, the mean age was 13.58 ± 9.81 months with slightly male predominant. Total duration of fever, intubation period, and length of hospital stay were 7.99 ± 4.28 , 5.29 ± 4.67 , and 12.47 ± 12.83 days, respectively. Viruses were more frequent causative-organisms than bacterias. Most of the mean values in basic laboratory findings as hematocrit, renal function, liver enzyme, and albumin were within a normal range. White blood cell counts revealed leukocytosis at mean 15516.56 ± 6649.06 cells/cu mm as shown in **Table 1**.

The admission date was 3.64 ± 1.80 days after the onset of fever. The first echocardiographic date was 9.46 ± 3.92 days after the onset of fever. The second round of laboratory investigations and echocardiography was performed 19.56 ± 5.67 days after admission. Of the 135 patients, ST/T changes occurred in 66 (49%), cardiac arrhythmia occurred in seven (5%), and myocardial injury occurred in 80 (59%). ST/T changes were a common finding from the ECGs. ST depression and ST elevation were observed in two patients. The remaining patients exhibited non-specific T-wave changes. Three cardiac arrhythmia patients exhibited premature ventricular contraction, premature atrial contraction, and first-degree atrioventricular block, and these conditions were resolved before discharge. Four patients exhibited right bundle branch blocks that persisted throughout the followed-up period. No hemodynamic

Table 1. Baseline characteristics of study population

Characteristics	Values
Age (months)	13.58 ± 9.81 (2–50)
Male	73 (54%)
Body mass index (kg/m ²)	17.88 ± 2.83 (11.7–30.5)
Peak of fever (celcius)	39.13 ± 0.74 (35.8–41)
Duration of fever before admission (days)	3.64 ± 1.80 (2–11)
Total duration of fever (days)	7.99 ± 4.28 (4–28)
Intubation period (days)	5.29 ± 4.67 (1–40)
Length of hospital stay (days)	12.47 ± 12.83 (4–128)
Laboratory index	
Type of infections	
Bacteria	54 (40%)
Virus	74 (55%)
Culture negative	7 (5%)
Complete blood count	
Hemoglobin (g/dL)	10.95 ± 1.38 (7.5–14.3)
Hematocrit (%)	32.80 ± 5.32 (24.1–42.1)
White blood count (cells/cu mm)	15516.56 ± 6649.06 (4570–37400)
Blood chemistry	
Blood urea nitrogen (mmol/L)	9.72 ± 4.41 (3–23.5)
Creatinine (mg/dl)	0.33 ± 0.10 (0.1–0.7)
Aspartate aminotransferase (IU/L)	56.63 ± 62.52 (5–615)
Alanine transaminase (IU/L)	42.92 ± 98.98 (7–691)
Albumin (g/dL)	4.18 ± 0.43 (2.5–5.2)

Data are presented as the mean \pm SD (range) or number (%) of patients.

Table 2. Cardiac laboratory measurements at admission date and second investigation date

Laboratory index	At admission date	Second investigation date	P
CXR: Cardiothoracic ratio	0.51 ± 0.04	0.48 ± 0.03	<0.001
Electrocardiogram			
Heart rate	146.34 ± 18.98	123.49 ± 19.23	<0.001
ST/T changes	66 (49%)	9 (7%)	0.035
Arrhythmia	7 (5%)	4 (3%)	<0.001
Myocardial injury	83 (62%)	16 (12%)	0.047
Troponin T (ng/mL)	0.04 ± 0.05	0.01 ± 0.02	<0.001

Data are presented as the mean \pm SD or number (%) of patients.

instability was observed in the arrhythmic group. The incidences of all of these conditions were significantly reduced by the second investigation, as shown in **Table 2**.

Valvular regurgitation occurred in 30 patients (22%) and pericardial effusion occurred in 80 patients (59%). The pericardial effusions were small to medium. Among all of the pericardial-effusion patients, 35 (44%) patients had small effusions and 45 (56%) patients had medium pericardial effusions with maximal thicknesses of 3.6 mm. Mitral and tricuspid valve regurgitations were observed in approximately 80 and 20% of the patients with valvular regurgitation, respectively. Echocardiogram revealed significant improvements of RVIMP, LVIMP, and LVEF at the second investigation date. Decreasing of pericardial effusion and right ventricular systolic pressure (RVSP) was also demonstrated. No significant changes of interventricular septum, left ventricular posterior wall thickening, and left ventricular diastolic dimension was demonstrated, as shown in **Table 3**. There were three mortality cases in this study, and all patients exhibited evidence of myocardial injury and CHF. Ventilator-associated pneumonia, acute respiratory distress syndrome, sepsis, septic shock, and death were developed after persisted clinical signs and symptoms of CHF.

Length of hospital stays was compared between presented cardiac-involvement patients (i.e., ST/T changes, arrhythmia, pericardial effusion, valvular regurgitation, and myocardial injury), and absent cardiac-involvement patients, as shown in **Table 4**.

Table 3. Echocardiographic measurements at first and second echocardiography

Echocardiographic parameters	First echocardiogram	Second echocardiogram	P
Valvular regurgitation	30 (22%)	2 (2%)	0.046
Pericardial effusion	80 (59%)	13 (9%)	0.002
Pericardial effusion (mm)	1.28 ± 1.09	0.17 ± 0.48	0.002
IVSs (mm)	9.17 ± 1.60	9.11 ± 1.61	0.780
IVSd (mm)	7.61 ± 1.40	7.49 ± 1.36	0.420
LVPWD (mm)	7.97 ± 1.65	7.84 ± 1.39	0.430
LVDD (mm)	24.97 ± 4.17	24.46 ± 4.70	0.130
LVEF (%)	70.99 ± 9.56	73.26 ± 11.26	0.040
LVIMP	0.46 ± 0.08	0.40 ± 0.05	<0.001
RVIMP	0.36 ± 0.09	0.30 ± 0.04	<0.001
RVSP (mmHg)	30.05 ± 5.97	24.91 ± 2.54	<0.001

Data are presented as mean ± SD or number (%) of patients. IVSs, interventricular septal thickness in systole; IVSd, interventricular septal thickness in diastole; LVPWD, left ventricular posterior wall diameter; LVDD, left ventricular end diastolic diameter; RVIMP, right ventricular index of myocardial performance; LVIMP, left ventricular index of myocardial performance; RVSP, right ventricular systolic pressure.

Table 4. Effects of cardiac involvement to length of hospital stay

Cardiac events	Length of hospital stay (days)		P
	Present	Absent	
ST/T changes	14.62 ± 16.74	10.68 ± 7.59	0.115
Arrhythmia	8.00 ± 2.94	12.65 ± 13.20	0.355
Pericardial effusion	12.06 ± 6.42	13.12 ± 19.11	0.702
Valvular regurgitation	15.67 ± 23.39	11.55 ± 7.46	0.122
Myocardial injury	13.99 ± 15.06	10.04 ± 7.61	0.082

Data are presented as mean ± SD.

Discussion

This study revealed that cardiac involvement occurred in up to 62% of the healthy children with CAP and RF. The effects possibly associated with infection, systemic inflammatory response, and cardiopulmonary interaction. Pericardial effusion, valvular regurgitation, ST/T changes, and non-fatal arrhythmia were rather common, but these conditions were mild and without severe hemodynamic effects. Myocardial injury was the most common finding but was typically asymptomatic, except for the patients who developed CHF.

Pericardial effusion and valvular regurgitation were possibly associated with an inflammation of the pericardium and valvular tissue. In agreement with the pericardial effusion results from our study, a previous study revealed evidence of pericardial effusion by computed tomography scan and echocardiography in approximately 50% of parapneumonic effusion patients [14]. This finding indicates the relationship between pulmonary and pericardial infectious processes [5]. The causative organism spreads to the pericardium via several routes that include pulmonary foci, the pleura, lymphatic channels of the hemithorax, and bacteremia [19]. However, the pericardial effusion cases with pulmonary infection included in our study typically exhibited mild to moderate pericardial effusion that resolved after treatment of the infection.

Abnormal ECG in this study was premature ventricular contraction, premature atrial contraction and first-degree atrioventricular block, ST segment elevation, and depression with non-specific T-wave changes. These were transient and disappeared after clinical improvement. The abnormal ECG findings possibly related to pericarditis and myocarditis because the causative organisms of pneumonia also cause both pericarditis and myocarditis [20]. In these conditions, non-specific ST/T-wave changes are common. However, ventricular conduction delays, supraventricular arrhythmia, and atrioventricular block are occasionally present [21, 22].

Incidences of myocardial injury approximately 60% were detected in our patients. Non-ischemic myocardial injury which reflected by increases in serum troponin levels was observed in critically ill patients without acute coronary syndrome [23, 24]. These findings were possibly due to myocarditis, systemic inflammatory responses and changes in circulatory volume [7, 25]. Viral-induced myocarditis results from various mechanisms, either direct infection of cardiac myocytes or emerging immune response. Although virus is the most common causative organism of pneumonia and myocarditis in this age group, bacteria also can cause both conditions [26-28]. Apart from direct infection of cardiac myocyte in bacterial infection, inflammatory cytokine, such as TNF- α and interleukin-6, were produced, causing myocardial inflammation and depression [24, 25].

The Tei index for myocardial performance revealed impairment of systolic and diastolic function in both ventricles upon admission that improved over the follow-up period. Although the initial LVEF values were within the normal range, significant improvements were observed on the second echocardiograms. In addition to myocardial depression related to infection and systemic inflammatory response which usually impact on LV dysfunction [25], the cardiopulmonary interaction and positive pressure ventilation have a potential effect on these findings. Positive pressure ventilation in RF patients causes compressive effects on both RV and LV. RV is compressed in cardiac fossa, decreased preload, and contractility with increased afterload due to increasing of pulmonary vascular resistance. LV is compressed in cardiac fossa, decreased LV preload, afterload, and compliance [29, 30]. Positive ventilation also affected intrathoracic and pulmonary pressure changes reflected by an increased RVSP on admission. Finally, it might impair cardiac function and develop low cardiac-output state.

Although the majority of cardiac involvement were mild and recovered spontaneously following pneumonia treatment, in case with progression to CHF, there were effects on hemodynamic compromise and multiorgan dysfunction. Risks of infection, such as ventilator associated pneumonia, ARDS and sepsis and prolong ventilatory support were increased. All complications have an impact on prolong hospitalization with increasing mortality.

Conclusions

CAP with RF is associated with cardiac involvements in as many as 62% of patients, even among healthy children without any cardiac risks. The majority of the complications, including myocardial injury, pericardial effusion, valvular regurgitation,

ST/T changes, and arrhythmia, were transient and mild in this group. Significant hemodynamic changes and increased mortality risks were observed in the patients who developed CHF. Future research should examine to identify characteristics and CHF with the aim of early recognition and prompt therapeutic strategy implementation.

Author contributions. Both authors made substantial contributions to the conception, design of the study, acquisition of the data, analyzed and interpreted the data. KN drafted the manuscript and WT critically revised it. Both authors approved the final version submitted for publication and take responsibility for the statements made in the published article.

Acknowledgment. The authors would like to thank Dr. Kritvikrom Durongpisitkul for consultation concerning conceptual reports and all pediatric staff and nurses for participation and support of the study.

Conflict of interest statement. The authors have completed and submitted the ICMJE Uniform Disclosure Form for Potential Conflicts of Interest. None of the authors disclose any conflict of interest.

References

- [1] Ghimire M, Bhattacharya SK, Narain JP. Pneumonia in south-east Asia region: public health perspective. *Indian J Med Res.* 2012; 135:459-68.
- [2] Gereige RS, Laufer PM. Pneumonia. *Pediatr Rev.* 2013; 34:438-56.
- [3] World Health Organization. Pneumonia. Fact sheet No. 331. [online]. 2013 [cited 2013 Apr 10]. Available from: <http://www.who.int/mediacentre/factsheets/fs331/en/>
- [4] Liu L, Oza S, Hogan D, Perin J, Rudan I, Lawn JE, et al. Global, regional, and national causes of child mortality in 2000-13, with projections to inform post-2015 priorities: an updated systematic analysis. *Lancet.* 2015; 385:430-40.
- [5] Pabary R, Balfour-Lynn IM. Complicated pneumonia in children. *Breathe.* 2013; 9:211-20.
- [6] Corrales-Medina VF, Suh KN, Rose G, Chirinos JA, Doucette S, Cameron DW, et al. Cardiac complications in patients with community-acquired pneumonia: a systematic review and meta-analysis of observational studies. *PLoS Med.* 2011; 8:e1001048.
- [7] Corrales-Medina VF, Musher DM, Wells GA, Chirinos JA, Chen L, Fine MJ. Cardiac complications in patients with community-acquired pneumonia: incidence, timing, risk factors, and association with short-term mortality. *Circulation.* 2012; 125:773-81.
- [8] Esposito S, Principi N. Unsolved problems in the approach to pediatric community-acquired pneumonia. *Curr Opin Infect Dis.* 2012; 25:286-91.
- [9] Kleinman ME, Chameides L, Schexnayder SM, Samson RA, Hazinski MF, Atkins DL, et al. Part 14: pediatric advanced life support: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation.* 2010; 122:S876-908.

- [10] Shah S, Sharieff GQ. Pediatric respiratory infections. *Emerg Med Clin North Am.* 2007; 25:961-79.
- [11] Giannitsis E, Kurz K, Hallermayer K, Jarausch J, Jaffe AS, Katus HA. Analytical validation of a high-sensitivity cardiac troponin T assay. *Clin Chem.* 2010; 56:254-61.
- [12] Wu AH, Ford L. Release of cardiac troponin in acute coronary syndromes: ischemia or necrosis? *Clin Chem Acta.* 1999; 284:161-74.
- [13] Zoghbi WA, Enriquez-Sarano M, Foster E, Grayburn PA, Kraft CD, Levine RA, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and echocardiography. *J Am Soc Echocardiogr.* 2003; 16:777-802.
- [14] Roberts JE, Bezack BJ, Winger DI, Pollack S, Shah RA, Cataletto M, et al. Association between parapneumonic effusion and pericardial effusion in a pediatric cohort. *Pediatrics.* 2008; 122:e1231-5.
- [15] Cickinson DF. The normal ECG in childhood and adolescence. *Heart.* 2005; 91:1626-30.
- [16] Lakoumentas JA, Panou FK, Kotseroglou VK, Aggeli KI, Harbis PK. The Tei Index of myocardial performance: applications in cardiology. *Hellenic J Cardiol.* 2005; 46:52-8.
- [17] Miller WT. Radiographic evaluation of the chest. In: Fisherman AP, editor. *Fisherman's pulmonary diseases and disorders.* Philadelphia: MacGraw-Hill; 2008, p. 454-509.
- [18] StataCorp L. *Stata Statistical Software: Release 13.* College Station, TX: StataCorp LP; 2013.
- [19] Augustin P, Desmard M, Mordant P, Lasocki S, Maury JM, Heming N, et al. Clinical review: intrapericardial fibrinolysis in management of purulent pericarditis. *Crit Care.* 2011; 15:220.
- [20] Caforio AL, Pankuweit S, Arbustini E, Basso C, Gimeno-Blanes J, Felix SB, et al. Current state of knowledge on aetiology, diagnosis, management, and therapy of myocarditis: a position statement of the European Society of Cardiology Working Group on Myocardial and Pericardial Diseases. *Eur Heart J.* 2013; 34:2636-48.
- [21] Morgera T, Di Lenarda A, Dreas L, Pinamonti B, Humar F, Bussani R, et al. Electrocardiography of myocarditis revisited: clinical and prognostic significance of electrocardiographic changes. *Am Heart J.* 1992; 124:455-67.
- [22] Morgera T, Di Lenarda A, Dreas L, Pinamonti B, Humar F, Bussani R, et al. Electrocardiography of myocarditis revisited: clinical and prognostic significance of electrocardiographic changes. *Am Heart J.* 1992; 124:455-67.
- [23] Ammann P, Maggiorini M, Bertel O, Haenseler E, Joller-Jemelka HI, Oechslin E, et al. Troponin as a risk factor for mortality in critically ill patients without acute coronary syndrome. *J Am Coll Cardiol.* 2003; 41:2004-9.
- [24] Moammar MQ, Ali MI, Mahmood NA, DeBer VA, Khan MA. Cardiac troponin I levels and alveolar-arterial oxygen gradient in patients with community-acquired pneumonia. *Heart Lung Circ.* 2010; 19:90-2.
- [25] Rudiger A, Singer M. Mechanism of sepsis-induced cardiac dysfunction. *Crit Care Med.* 2007; 35:1599-608.
- [26] Ruuskanen O, Lahti E, Jennings LC, Musdoch DR. Viral pneumonia. *Lancet.* 2011; 377:1264-75.
- [27] Vikki R, Juven T, Rikalainen H, Svedstrom E, Mertsola J, Ruuskanen O. Differentiation of bacterial and viral pneumonia in children. *Thorax.* 2002; 57:438-41.
- [28] Gereige RS, Laufer PM. Pneumonia. *Pediatr Rev.* 2013; 34:438-55.
- [29] Smeding L, Lust E, Plotz FB, Groeneveld ABJ. Clinical implications of heart-lung interactions during mechanical ventilation: an update. *Neth J Med.* 2010; 68:56-61.
- [30] Pinsky MR. Cardiovascular issues in respiratory care. *Chest.* 2005; 128:592S-7S.