2010
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Death in the line of duty...

NIOSH
Fire Fighter Fatality Investigation and Prevention Program

A summary of a NIOSH fire fighter fatality investigation *June, 2010*

Captain Dies After Extremely Heavy Physical Exertion at Building Fire from Complications of Mitral Valve Surgery– Kansas

Executive Summary

On December 13, 2009, a 51-year-old male career Captain responded to a fire in a condominium complex clubhouse. On scene while wearing full turnout gear, he stretched a 2 1/2- and a 3-inch hoseline and cut a hole in the building exterior to access the crawl space. While in rehabilitation (rehab), the Captain experienced persistent shortness of breath and palpitations/tachycardia. These symptoms progressed over the next few days resulting in a subsequent diagnosis of mitral valve insufficiency/regurgitation. The Captain underwent surgery to repair his mitral valve on December 29, but suffered an intra-operative myocardial infarction (heart attack) from which he died 4 days later. The death certificate, completed by the pathologist, listed the cause of death as "massive acute myocardial infarction due to complications from mitral valve annulus placement due to severe mitral regurgitation aggravated by smoke/chemical inhalation." The autopsy, completed by the pathologist, listed "massive acute myocardial infarction secondary to kinking and obstruction of the circumflex coronary artery resulting from the mitral valve annulus placement during mitral valve surgery" as the cause of death. NIOSH investigators agree with these conclusions. In addition, NIOSH investigators believe that the Captain's acute mitral value insufficiency/regurgitation was due to a partial tear/rupture of his chordae tendineae. This tear/detachment was probably triggered by the heavy physical exertion expended during fire suppression activities on December 13, 2009.

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unlikely that any of these recommendations could have prevented the Captain's death.

Provide annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Discontinue routine pre-employment/ preplacement exercise stress tests for applicants.

Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Phase in a comprehensive wellness and fitness program for fire fighters.

Perform an annual physical performance (physical ability) evaluation.

Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.

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Introduction & Methods

On December 13, 2009, a 51-year-old male career Captain had persistent palpitations and shortness of breath in rehab at a structure fire. Subsequent testing revealed mitral valve insufficiency/regurgitation. The Captain underwent surgery to repair the mitral valve insufficiency/regurgitation on December 29, 2009. The Captain died 4 days later. The U.S. Fire Administration notified NIOSH of this fatality on January 4, 2010. NIOSH contacted the affected fire department (FD) to gather additional information on January 5, 2010, and on February 4, 2010, to initiate the investigation. On February 22, 2010, a Safety and Occupational Health Specialist from the NIOSH Fire Fighter Fatality Investigation Team traveled to Kansas to conduct an on-site investigation of the incident.

During the investigation, NIOSH personnel interviewed the following people:
- Fire Chief
- Fire Marshal
- Deputy Fire Chief
- Safety/Training Chief
- International Association of Fire Fighters (IAFF)
- Local President
- IAFF local secretary
- The Captain's family representative
- Crew members

NIOSH personnel reviewed the following documents:
- FD policies and operating guidelines
- FD training records
- FD annual report for 2009
- FD incident reports
- Witness statements
- Hospital emergency department (ED) records
- Hospital inpatient records
- Death certificate
- Autopsy report
- Primary care physician records

Investigative Results

Incident. On December 13, 2009, the Captain arrived for his 24-hour shift at Station 11 (Engine 11) at 0700 hours. Two fire fighters were assigned with the Captain. At 0903 hours, the FD was dispatched to a fire in a condominium clubhouse. The 5,000-square-foot clubhouse was a single story wood frame structure with a basement. Engine 9, Engine 20, Aerial Platform 9, Quint 15, Squad 11, Squad 14, Battalion 9, Safety Officer, and Medical Officer responded on the first alarm. Units began arriving on scene at 0909 hours and found heavy smoke conditions. Fire fighters entered the structure to find moderate heat conditions, zero visibility, and a collapsed floor. They began fire extinguishment without success and backed out of the structure. Aerial 9 ventilated the roof. Weather conditions at an airport 2 miles away included fog, light drizzle, a temperature of 41 degrees Fahrenheit, 100% relative humidity, and south-southeast winds at 14 miles per hour [NOAA 2009].

A second alarm dispatched the following units at 0918 hours: Engine 6, Engine 10, Engine 11 (the Captain and two fire fighters), Engine 5, Engine 12, Quint 14, Quint 4, Quint 18, Squad 5, Squad 19, and Squad 36. Engine 11 arrived into staging and then was assigned to turn off the natural gas to the building. The crew arrived at the building wearing their self-contained breathing apparatus (SCBA) and carrying tools. After the gas was turned off, Incident Command declared a defensive operation, and hoselines were moved to begin this phase. The Incident Safety Officer noticed the Captain's "color not being so great" and the Captain seemed to be "winded."

Engine 11 was assigned to the C/D division with the Captain in command. Using a chain saw, the Engine 11 crew cut a hole in the side of the build-

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Investigative Results (cont.)

ing to access the fire using a 1¾-inch hoseline. Unable to reach the fire, command advised crews to prepare for "master stream" application. Crews used two preconnected hoselines to protect the C/D side until a 3-inch hoseline with monitor was set up. After approximately 1 hour on scene, Engine 11 entered rehab for rest and hydration (1022 hours).

In rehab, the Captain's pulse rate was fast (114 beats per minute). Despite removing his turnout gear and resting for 5 minutes, his tachycardia remained. After 30-45 minutes in rehab, the Captain's pulse returned to the upper threshold limits and he was released (1052 hours). The fire was declared under control at 1100 hours, and crews began to gather equipment. The Captain assisted in rolling hoselines and moving heavy equipment between engines. The crew returned to the fire station at 1341 hours.

Although the Captain's symptoms of palpitations and shortness of breath transiently improved after the fire, his symptoms returned and persisted the remainder of his shift and further deteriorated over the next 5 days. On December 18, 2009, the Captain sought medical evaluation from his primary care physician, who found a loud heart murmur (holosystolic 3/6 at the apex) and ordered an electrocardiogram (EKG), which revealed sinus tachycardia (111 beats per minute) with left ventricular hypertrophy (LVH). He was referred to a cardiologist whose echocardiogram diagnosed mitral valve prolapse with severe mitral valve regurgitation (posterior leaflet). His echocardiogram also showed a normal left ventricular ejection fraction (55%–60%) and no LVH; both findings suggest a recently acquired problem. He was prescribed medication to control his heart rate, and arrangements were made for mitral valve surgery on December 29, 2009. The next day, however, the Captain was admitted to the hospital for mild congestive heart failure secondary to mitral valve regurgitation/ insufficiency. A transesophageal echocardiogram (TEE) confirmed the previous echocardiology findings and a cardiac catheterization revealed no evidence of coronary artery disease with a normal left ventricular ejection fraction. He was treated with diuretics and discharged on December 22 to return on December 28 for his mitral valve repair/replacement surgery on December 29, 2009.

On December 29, 2009, an intraoperative TEE showed an enlarged left atrium and mild concentric LVH with normal cardiac output. Anterior and posterior leaflets of the mitral valve were thickened and myxomatous, resulting in severe mitral valve prolapse. Portions of the posterior leaflet and corresponding chordae were either detached or seriously disrupted, resulting in the mitral valve insufficiency/regurgitation. The intraoperative TEE was followed by the surgical repair of the mitral valve. An intraoperative TEE following the repair showed a markedly hypokinetic left and right ventricle. The inferior and posterior portions of the left ventricle were severely hypokinetic, if not akinetic. Four days after the surgery the Captain died from complications of the surgery.

Medical Findings. The death certificate, completed by the pathologist, listed "massive acute myocardial infarction due to complications from mitral valve annulus placement due to severe mitral regurgitation aggravated by smoke/chemical inhalation." Further, a medical opinion provided by the Medical Intensive Cardiac Unit Medical Director stated "The sudden and persistent chang-

Investigative Results (cont.)

es in the Captain's physical condition after fighting the structure fire on December 13th are consistent with acute rupture of chordate tendineae to the posterior leaflet on the mitral valve caused by a period of extreme physical exertion while fighting the structure fire." The autopsy, completed by the pathologist, listed "massive acute myocardial infarction [heart attack] secondary to kinking and obstruction of the circumflex coronary artery resulting from the mitral valve annulus placement during mitral valve surgery" as the cause of death. Specific findings from the autopsy are listed in Appendix A.

The Captain's last medical evaluation was conducted in 2008 as part of a one-time grant. This evaluation was significant for no history of angina, a normal pulse, and no heart murmur. As part of this evaluation the Captain had a treadmill exercise stress test (EST) at which time the record mentions a history of "heart beat skipping a beat at about 120 bpm [beats per minute]." Results of the EST show the Captain exercised for 10 minutes, 10 seconds of the Bruce protocol, achieving 12.1 metabolic equivalents (METS). The test was stopped when the Captain reached 100% of his target heart rate. He experienced no angina, had a normal blood pressure response to the exercise, had no arrhythmias, and had no ischemic changes. Prior to the incident described in this report, the Captain never reported episodes of shortness of breath on exertion, angina, palpations, or any other cardiac problems to his family or the FD.

Description of the Fire Department

At the time of the NIOSH investigation, the career FD consisted of 22 fire stations with 440 uniformed personnel that served a population of 368,000 residents in a geographic area of 168 square miles.

In 2009, the FD responded to 42,876 calls: 1,645 fires, 1,117 hazardous condition calls, 63 overpressure calls, 1,632 system alarms, 4,315 good intent calls, 2,663 public service calls, 31 weather-related calls, 58 other service calls, and 31,352 medical calls.

Employment and Training. The FD requires all fire fighter candidates to pass a general aptitude test and a physical ability test. The FD ranks applicants based on their scores. The FD then interviews the top 30% and gives credit for relevant college classes, experience, and technical training. A new list is formed, and depending on the number of fire fighters to be hired, the FD offers positions to the top candidates pending results of a physical examination and drug screen. License and background checks are conducted, as well as verification of Emergency Medical Technician (EMT) training. The recruit class is formed, and recruits attend a 10-week FD academy. New recruits are then assigned to a fire station and, after one year of probation, are given the basic Fire Fighter-I skills test. Further training to Fire Fighter-II is conducted in the fire station until the Fire Fighter-II examination has been passed. The Captain was certified as a Fire Fighter II, Fire Officer I, EMT, in HazMat operations, and Technical Rescue. He had 28 years of fire fighting experience.

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Description of the Fire Department (cont.)

Preplacement Medical Evaluation. A preplacement medical examination is required by this FD for all applicants. The contents of the examination are as follows:

- Complete medical and occupational history
- Height, weight, and vital signs
- Physical examination
- Blood tests: complete blood count, lipid panel, and liver profile
- Urine tests: urinalysis and urine drug screen
- Chest x-ray (posteroanterior and lateral views) with interpretation and report
- 12-lead resting EKG with interpretation and report
- Treadmill EST
- Audiometry
- Vision test
- Functional capacity evaluation

These evaluations are performed by a physician under contract to the City. Once this evaluation is complete, the physician makes a determination regarding medical clearance for fire fighting duties and forwards this decision to the FD.

Periodic Medical Evaluations. Required medical evaluations are offered every other year to hazardous materials (hazmat) technician-level responders assigned to the Hazmat team. A City-contracted physician performs the medical evaluations and forwards the clearance-for-duty decision to the FD, which makes the final determination. The FD offered a medical evaluation for all fire fighters in 2008 paid for by a Federal grant, but participation was voluntary. As mentioned earlier, the Captain had the evaluation in 2008.

Health and Wellness Programs. No physical agility test is required for members, but the FD has a voluntary fitness program where exercise equipment (strength and aerobic) is available in all fire stations. A return-to-duty medical clearance is required from the City-contracted physician for duty-related injuries. Fire fighters who miss more than five shifts due to illness must have a release from their primary care physician before they may return to work. There is no medical component to the SCBA program, but a fit test is performed annually. Health maintenance programs are available through the City employee assistance program.

Discussion

Mitral Valve Prolapse. Mitral valve prolapse occurs when one or both of the mitral valve leaflets prolapse into the left atrium during systole (contraction of the heart muscle). It is the most common heart valve disorder, affecting about 2%–4% of the population. Both sexes and all ages can be affected [O'Gara and Braunwald 2008]. The prolapse can be due to problems with the valve leaflets or other parts of the mitral valve apparatus (e.g., annulus; chordae tendineae; papillary muscles; and the supporting walls of the left ventricle, left atrium, and the aorta) [Bonow et al. 2006; Gabbay and Yosefy 2010]. Problems with the valve leaflets are classified as primary mitral valve prolapse (Appendix B).

The basic microscopic feature of primary mitral valve prolapse is marked thickening and redundancy of the middle layer of the valve leaflet (myxomatous proliferation of the spongiosa connective tissue) [Bonow et al. 2006]. During surgery, the Captain's mitral valve was noted to be myxomatous. Clinical presentations of mitral valve prolapse range from asymptomatic heart murmurs to severe mitral valve regurgitation with symptoms of fatigue, shortness of breath on exertion, and reduced exercise tolerance [O'Gara and Braunwald 2008]. The diagnosis is made by echocardiography, which measures the abrupt posterior movement of one or both of the mitral valve leaflets [Malkowski and Pearson 2000]. The EKG is usually normal in asymptomatic patients, but more severe cases can show signs of LVH. Prior to this incident, the Captain did not have any symptoms associated with a mitral valve prolapse, nor did he present with LVH on his echocardiogram.

Like the clinical presentation, the clinical course and prognosis are variable. Patients can remain asymptomatic, but some cases progress over decades to severe regurgitation, putting the patient at risk for endocarditis (infection of the heart valve), strokes, and arrhythmias. Arrhythmias associated with mitral valve prolapse can cause palpitations, lightheadedness, and syncope. The Captain's symptoms of palpitation were probably related to an arrhythmia associated with his mitral value prolapse. His more recent symptoms of fatigue and shortness of breath were probably related to the acute (sudden onset) tear/rupture of the chordae tendineae causing mitral valve insufficiency/regurgitation.

Mitral Valve Insufficiency/Regurgitation. Chordae tendineae rupture of any mitral valve leaflet is the most common cause of acute mitral regurgitation requiring prompt surgery. Chordae arising from a myxomatous mitral valve are likely to tear or rupture at a lower tensile stress or at a lower absolute load [Barber et al. 2001]. In addition, extreme physical exertion can trigger or precipitate an acute chordate rupture in a myxomatous valve, resulting in acute mitral regurgitation [Brizzio and Zapolanski 2008]. The Captain's mitral insufficiency/regurgitation was probably due to an acute rupture/tear of the chordae tendineae of his mitral valve's posterior leaflet. The chordae tear/rupture was probably due to a combination of his underlying myxomatous valve and the heavy physical exertion expended during fire suppression activities on December 13, 2009.

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Discussion (cont.)

Occupational Medical Standards for Structural Fire Fighters. To reduce the risk of sudden cardiac arrest or other incapacitating medical conditions among fire fighters, the NFPA developed NFPA 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments [NFPA 2007a]. This voluntary industry standard provides medical requirements for candidates and current fire fighters. The Captain's last FD medical evaluation was in 2008. In this case, the Captain's last medical evaluation indicated no mitral valve prolapse. If a mitral valve prolapsed had been detected, as part of an earlier diagnosis, the diagnosis would probably not have precluded the Captain's work as a fire fighter or prevented his death.

Recommendations

NIOSH investigators offer the following recommendations to address general safety and health issues. However, it is unlikely that any of these recommendations could have prevented the Captain's death.

Recommendation #1: Provide annual medical evaluations to all fire fighters consistent with National Fire Protection Association (NFPA) 1582, Standard on Comprehensive Occupational Medical Program for Fire Departments.

Guidance regarding the content and frequency of these evaluations can be found in NFPA 1582 and in the International Association of Fire Fighters (IAFF)/ International Association of Fire Chiefs (IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative [NFPA 2007a; IAFF, IAFC 2008]. These guidelines help to determine fire fighters' medical ability to perform duties without presenting a significant risk to the safety and health of themselves or others. However, the FD is not legally required to follow this standard or this initiative. This recommendation is unlikely to have prevented his work as a fire fighter or prevented his death from complications of his mitral valve surgery.

The FD requires hazmat medical evaluations for hazmat team members. As part of this evaluation, the FD is conducting routine chest x-rays and blood testing for heavy metals and aromatic hydrocarbons. While these tests may be indicated for hazmat fire fighters exposed to specific chemicals, they should not be conducted routinely and represent an unnecessary expense for the FD. The FD should consider re-evaluating the scope of its hazmat medical evaluation [DHHS 1985].

Recommendations (cont.)

Recommendation #2: Discontinue routine pre-employment/preplacement exercise stress test.

Currently the FD is conducting an exercise stress test on all applicants during their preplacement medical evaluation, regardless of the number or severity of their coronary artery disease (CAD) risk factors. This testing represents an unnecessary medical expense for the FD. The American Heart Association/American College of Cardiology and NFPA 1582 recommend an exercise stress test only for people/FFs at increased risk for CAD. NFPA defines increased risk as two or more CAD risk factors in male FFs over the age of 45 and female FFs over the age of 55 [Gibbons et al. 2002; NFPA 2007a].

Recommendation #3: Ensure fire fighters are cleared for return to duty by a physician knowledgeable about the physical demands of fire fighting, the personal protective equipment used by fire fighters, and the various components of NFPA 1582.

Currently, a State Workers' Compensation physician reviews and approves return to duty clearances for fire fighters injured on duty. For long-term illnesses, the fire fighter's personal physician approves return to duty. These physicians may not be aware of the physiological and psychological demands on fire fighters, the environmental conditions under which they must perform, and the personal protective equipment fire fighters must wear during various types of emergency operations. Therefore, we recommend the FD have an officially designated physician who is responsible for guiding, directing, and advising the members with regard to their health, fitness, and suitability for duty [NFPA 2007a; NFPA 2007b; IAFF, IAFC 2008].

Recommendation #4: Phase in a comprehensive wellness and fitness program for fire fighters.

Guidance for fire department wellness/fitness programs is found in NFPA 1583, Standard on Health-Related Fitness Programs for Fire Fighters, the International Association of Fire Fighters/ International Association of Fire Chiefs (IAFF/ IAFC) Fire Service Joint Labor Management Wellness/Fitness Initiative, and in the Firefighter Fitness: A Health and Wellness Guide [USFA 2004; IAFF, IAFC 2008; NFPA 2008; Schneider 2010]. Worksite health promotion programs have been shown to be cost effective by increasing productivity, reducing absenteeism, and reducing the number of work-related injuries and lost work days [Stein et al. 2000; Aldana 2001]. Fire service health promotion programs have been shown to reduce CAD risk factors and improve fitness levels, with mandatory programs showing the most benefit [Dempsey et al. 2002; Womack et al. 2005; Blevins et al. 2006]. A study conducted by the Oregon Health and Science University reported a savings of over $1 million for each of four large fire departments implementing the IAFF/IAFC wellness/fitness program compared to four large fire departments not implementing a program. These savings were primarily due to a reduction of occupational injury/ illness claims with additional savings expected from reduced future nonoccupational healthcare costs [Kuehl 2007]. NIOSH recommends a formal, structured wellness/fitness program to ensure all members receive the benefits of a health promotion program.

Recommendation #5: Perform an annual physical performance (physical ability) evaluation.

Recommendations (cont.)

NFPA 1500 recommends fire department members who engage in emergency operations be annually evaluated and certified by the FD as having met the physical performance requirements identified in paragraph 10.2.3 of the standard [NFPA 2007b]. This is recommended to ensure fire fighters are physically capable of performing the essential job tasks of structural fire fighting. The physical ability test could be performed as part of the FD's annual training program.

Recommendation #6: Provide fire fighters with medical clearance to wear self-contained breathing apparatus as part of the Fire Department's annual medical evaluation program.

The Occupational Safety and Health Administration (OSHA) Revised Respiratory Protection Standard requires employers to provide medical evaluations and clearance for employees using respiratory protection prior to being fit tested [29 CFR1 1910.134]. Employees must receive annual medical evaluations to determine fitness for duty to wear personal protective equipment (respirators), unless the physician believes a semiannual evaluation is appropriate 29 CFR 1910.120]. These clearance evaluations are required for private industry employees and public employees in States operating OSHA-approved State plans [OSHA 2010]. The clearances are completed as part of the fire department medical evaluation program. Kansas does not operate an OSHA-approved State plan for the public sector; therefore, public sector employers (including volunteer/paid fire departments) are not required to comply with OSHA standards. However, NIOSH investigators recommend following this standard to ensure an increased level of medical fitness and safety.

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Investigator Information

This incident was investigated by the NIOSH Fire Fighter Fatality Investigation and Prevention Program, Cardiovascular Disease Component located in Cincinnati, Ohio. Mr. Tommy Baldwin (MS) led the investigation and co-authored the report. Mr. Baldwin is a Safety and Occupational Health Specialist, a National Association of Fire Investigators (NAFI) Certified Fire and Explosion Investigator, an International Fire Service Accreditation Congress (IFSAC) Certified Fire Officer I, and a former Fire Chief and Emergency Medical Technician. Dr. Thomas Hales (MD, MPH) provided medical consultation and co-authored the report. Dr. Hales is a member of the NFPA Technical Committee on Occupational Safety and Heath, and Vice-Chair of the Public Safety Medicine Section of the American College of Occupational and Environmental Medicine (ACOEM).

Appendix A

Autopsy Findings

- Cardiac
  - Acute transmural myocardial infarction (MI) involving approximately 50% of the left ventricle and 50% of the right ventricle beginning at the apex and extending to the valve rings with a gross age of approximately 4 days (December 31, 2009)
  - Circumflex coronary artery has a severe 90-degree kink with obstruction of the lumen as it abuts and touches the prosthetic annulus placed in the mitral valve ring
  - Left circumflex coronary artery discolored distal to the kink compatible with intraluminal thrombosis
  - Cardiomegaly (enlarged heart) (heart weighed 590 grams [g]; predicted normal weight is 358 g [ranges between 271 g and 473 g as a function of sex, age, and body weight]) [Silver and Silver 2001]
  - Mild (25%) focal narrowing of the left anterior descending coronary artery
  - No focal narrowing of the right coronary artery
  - No atherosclerosis in circumflex coronary artery
  - Mitral valve repair with one broken suture in the lateral portion of the annulus
  - Normal aortic, tricuspid, and pulmonic valves
- No evidence of a pulmonary embolus (blood clot in the lung arteries)
- Acute fibrinous pericarditis
- Pulmonary edema and intra-alveolar hemorrhage
- Extensive centrilobular necrosis and congestion of the liver
- Extensive acute tubular necrosis of the kidneys
- Renal fibrin thrombi consistent with disseminated intravascular coagulation
- Acute interstitial pancreatitis
- Congestive splenomegaly
- Steatosis of the liver

Microscopic examination of the left and right ventricles revealed extensive myocyte necrosis with neutrophilic inflammation with hemorrhage and degeneration of the neutrophils consistent with an infarct of 4 days of age.

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Appendix B

Classification of Mitral Valve Prolapse [Bonow et al. 1998]

Primary Mitral Valve Prolapse
- Familial
- Nonfamilial
- Marfan's syndrome
- Other connective tissue diseases

Secondary MVP
- Coronary artery disease
- Rheumatic heart disease
- Reduced LV dimensions
  - Hypertrophic cardiomyopathy
  - Atrial septal defect
  - Pulmonary hypertension
  - Anorexia nervosa
  - Dehydration
  - Straight-back syndrome/pectus excavatum
  - "Flail" mitral valve leaflet(s)

Normal variant
- Inaccurate auscultation

"Echocardiographic heart disease"