

Original Article

## AECVP and SCVP 2009 Recommendations for Training in Cardiovascular Pathology

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### Abstract

Cardiovascular disease is of continuing importance as the result of a growing burden of risk factors in both developing and developed countries and the increasing number of elderly people worldwide. The recruitment and training of a new generation of Cardiovascular Pathologists is crucial to sustaining clinical excellence and to advancing our knowledge of cardiovascular disease. These pathologists will also have a key role in undergraduate and postgraduate training. In 2005 a task force of the Society for Cardiovascular Pathology published a

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document on the role of Cardiovascular Pathology as subspecialty of Anatomical Pathology (Pathological Anatomy). The 2005 report emphasized the need for a core curriculum and structured learning for residents and fellows in Cardiovascular Pathology. This new consensus statement on training is the result of collaboration between Cardiovascular Pathology Societies based in Europe and North America. It includes a detailed curriculum and describes three levels of expertise that can be developed. © 2010 Elsevier Inc. All rights reserved.

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## 1. Introduction

The global epidemic of cardiovascular disease is the result of a growing burden of risk factors in both developing and developed countries and the increasing number of elderly people worldwide. However, extraordinary advances in preventive medicine, clinical diagnosis and pharmacological and nonpharmacological treatments resulted in a 6-year increase in life expectancy in the United States between 1970 and 2000. Nearly two thirds of this is due to reduction in cardiovascular disease [1].

Cardiovascular Pathologists have made major steps forward during this period, and previously [2]. They have contributed to:

1. Advances in knowledge of the pathological anatomy and clinicopathological features of a wide variety of cardiovascular abnormalities including the postoperative pathology of congenital and acquired heart disease;
2. Preclinical development and clinical validation of cardiovascular imaging techniques, devices and prostheses, and recognition of their complications;
3. Evaluation of diagnostic endomyocardial biopsy specimens and the myocardial changes associated with transplantation, both in vivo by graft rejection monitoring by endomyocardial biopsy and by the study of explanted hearts;
4. Our understanding of atherosclerosis, especially the concept of plaque vulnerability and its role in the

precipitation of coronary thrombosis, myocardial infarction and sudden death;

5. Studies of the timing and progression of myocardial injury caused by ischemia, with and without reperfusion injury;
6. Discovery of novel conditions that cause sudden death, especially in the young;
7. Our understanding of degenerative valve disease, the clinicopathological features of infectious endocarditis, inflammatory valvulitis and aortitis and systemic vasculitis;
8. Our knowledge of the etiology of myocarditis, toxic and genetically determined cardiomyopathies largely through application of molecular techniques; and
9. Studies of phenotypes and genetic abnormalities in primary cardiac tumors.

Major advances in cardiovascular medicine have widened the spectrum of investigations, diagnostic needs and increased the potential role of Cardiovascular Pathologists. As in other areas of diagnostic pathology, the numbers of requests have risen. Autopsies are performed with higher expertise and more accurate understanding of clinical physiology. Molecular techniques are of increasing importance, as is collaboration with industry [3–6]. Regrettably, there is a global shortage of expertise in the field. The recruitment and training of a new generation of cardiovascular pathologists is crucial to sustaining clinical excellence and to advancing our knowledge of cardiovascular disease. These pathologists will also have a key role in undergraduate and postgraduate training.

In 2005, a task force of the Society for Cardiovascular Pathology published a state-of-the-art document on the role of cardiovascular pathology as subspecialty of anatomical pathology (pathological anatomy). It described the demands on cardiovascular pathologists that have followed clinical advances. It also summarized current opportunities for

Table 1  
Level 1

Basic knowledge of anatomy and heart dissection
Heart weight (in relation to body size)
Coronary arteries and their pattern of distribution: left main, left anterior descending, left circumflex, right, posterior descending, obtuse marginal, diagonals
Methods of heart dissection: indications and techniques
Flow of blood
Short axis
Long axis
Four chamber
Valves:
Semilunar: cusp number, free edge, closing edge, fenestrations, commissures, annulus
Atrioventricular: annulus, leaflets, commissures, chordae, papillary muscles
Atria and ventricles
Size and wall-septal thickness
Optimal preservation of the heart for expert consultation

Table 2  
Level 1

Aortic diseases
Congenital/genetic: bicuspid aortic valve, coarctation, patent ductus arteriosus, William's syndrome
Atherosclerosis: plaques, thrombosis, penetrating aortic ulcer, aneurysm
Dilatation and/or dissection, with or without medial "necrosis" (hypertension, Marfan's, bicuspid aortic valve)
Aortitis (infective: syphilis, mycotic aneurysm; or non-infective: giant cell, Takayasu): dilatation, dissection
Trauma: rupture, dissection
Vascular prostheses (grafts and endovascular stents)

Table 3  
Level 1

Coronary artery disease
Atherosclerotic
Mural and occlusive thrombosis, plaque rupture
Estimation of arterial stenosis ( $\leq 75\%$ or $>75\%$ )
Analysis of bypass grafts—venous and arterial
Analysis of stents, percutaneous transluminal coronary angioplasty
Analysis of material aspirated from arteries and grafts
Non atherosclerotic
Congenital
Anomalous origin and course of coronary arteries
Acquired
Arteritis
Dissection
Embolism

Cardiovascular Pathology training in North America and Europe [7]. The 2005 report emphasized the need for a core curriculum and structured learning for residents and fellows in Cardiovascular Pathology.

This new consensus statement is the result of collaboration between Cardiovascular Pathology Societies based in Europe and North America. It includes a detailed curriculum and describes varying levels of expertise that can be developed. The guidelines represent a consensus of members of the current task force. We accept that our recommendations are ambitious, especially as recruitment of young doctors into pathology is difficult. It is understood that local and regional priorities, cultures and laws, standards of care, and resource constraints will lead to different patterns of training and practice in cardiovascular pathology. Nevertheless we hope that our document will be used by directors of pathology training programmes as a model of how training in cardiovascular pathology should develop.

Three levels of expertise are suggested:

## 2. Level 1

This level is the minimum training in cardiovascular pathology for pathologists working in hospitals with neither cardiac and vascular surgery nor interventional cardiology. It

Table 4  
Level 1

Ischemic heart disease
Acute myocardial infarction
Macroscopic and microscopic methods for recognizing and dating of infarcts (including enzymatic/chemical methods for gross detection, e.g., nitro blue tetrazolium and triphenyl tetrazolium chloride)
Subendocardial versus transmural infarcts
Ischemic lesions altered by reperfusion
Complications (arrhythmic death, cardiac rupture, cardiogenic shock, ventricular aneurysm, mural thrombosis, thromboembolism)
Chronic ischemic heart disease
Myocardial scarring with/without aneurysm

Table 5  
Level 1

Cardiac tumors
Secondary (metastatic)
Primary
Benign
Myxoma
Papillary fibroelastoma
Lipomatous hypertrophy of inter-atrial septum
Malignant
Sarcoma
Mesothelioma
Lymphoma
Non-neoplastic masses

is also the minimum knowledge that forensic pathologists should acquire.

Knowledge of cardiovascular anatomy and different techniques for the dissection of the heart is of primary importance (Table 1). Additionally, recognition of specific pathological conditions in aortic disease (Table 2), coronary artery diseases (Table 3), ischemic heart disease (Table 4), cardiac tumors (Table 5), cardiomyopathies (Table 6), hypertensive heart disease (Table 7), pericardial disease (Table 8), peripheral vascular disease (Table 9), cerebrovascular disease (Table 10), sudden death in general (Table 11), valvular heart disease (Table 12), and effects of drugs on the heart (Table 13) is desirable.

Level 1 skills and competences in cardiovascular pathology are recommended for all anatomic pathology residents who expect to perform autopsies or teach undergraduates as trained pathologists. This should be an integral part of training in anatomical pathology. It is unlikely that practicing pathologists will maintain expertise in all of the fields described in Tables 2 through 13. However a basic training in cardiovascular pathology will enable practicing pathologists to identify appropriate cases for referral to specialists. Continuing education in cardiovascular pathology should be offered and is described below as a role of full time specialists in cardiovascular pathology (Level 3).

Table 6  
Level 1

Cardiomyopathies
Primary
Dilated
Arrhythmogenic right ventricular
Hypertrophic
Restrictive
Secondary
Infiltrative: amyloid
Storage: hemochromatosis, glycogenosis
Myocarditis: lymphocytic, giant cell, sarcoid, eosinophilic
Loeffler eosinophilic fibroplastic endocarditis, Davies
endomyocardial fibrosis
Anthracycline and other toxicities

Table 7  
Level 1

Hypertensive heart disease
Systemic arterial hypertension
Atherosclerosis
Left ventricular hypertrophy
Left atrial dilatation/appendage thrombosis
Stroke
Aortic dissection
End organ damage (kidney, brain)
Pulmonary vascular hypertension
Pulmonary artery atherosclerosis
Pulmonary vascular disease
Right ventricular hypertrophy

### 3. Level 2

This level of training is recommended for a Pathologist working in a hospital with Cardiac and Vascular Surgery facilities and/or Interventional Cardiology. There will be increasing demand for this level of expertise as the number of hospitals offering emergency and routine angioplasty increases.

In addition to the Level 1 postmortem skills, these pathologists will perform complex autopsies following cardiac surgery or interventions. Knowledge of the various surgical and interventional endovascular prostheses/devices is therefore needed. These include closure devices, intra-aortic balloon pumps, mechanical and biological prosthetic valves, stents, embolic protection devices, vascular prostheses, cardiac resynchronization pacemakers and implantable cardioverter defibrillators (Table 14). An outline knowledge of the physiological function of these devices, their complications and structural deterioration is required. In terms of surgical pathology, experience of biopsies of the aortic wall and other vessels; endarterectomies; valve replacements, and biopsies of the pericardium, the lung, and cardiac and extracardiac masses is essential (Table 15). A basic knowledge of diagnostic endomyocardial biopsy and transplant biopsy interpretation is desirable, although it is recognized some specimens may be referred to Level 3 centers.

Full training in anatomic pathology should be completed with an additional specific experience in cardiovascular pathology. We suggest 3 to 6 months experience in a Level 3 centre. A longer Fellowship, perhaps with complimentary experience in pulmonary pathology, would be ideal.

Table 8  
Level 1

Pericardial disease
Acute pericarditis (serous, fibrinous, purulent, hemorrhagic)
Chronic adhesive pericarditis
Constrictive pericarditis ± calcification
Primary and secondary tumor involvement

Table 9  
Level 1

Peripheral vessel disease
Atherosclerosis plaque
Fibromuscular dysplasia
Mönckeberg's medial calcific arteriosclerosis
Trauma
Vascular prostheses, bypass, stent, protection devices
Vascular tumors
Vasculitis

### 4. Level 3

These Pathologists occupy full time positions in an academic medical center or a specialist cardiovascular hospital. They have a major commitment to cardiovascular pathology. Some pathologists currently practicing at this level are able to devote themselves exclusively to cardiovascular pathology. Others contribute to subspecialties, especially pulmonary pathology. They have the skills described for Levels 1 and 2 above, but with enhanced clinical and pathological experience and expertise. In particular, they use electron microscopy and molecular techniques to make and refine diagnoses. To support cardiac electrophysiologists, expertise in the study of the conduction system by serial section techniques, ablation procedures and their consequences, and the pathological examination of devices implanted for rhythm and conduction disorders is important (Table 16). Examination of ventricular assist devices will also be required. Complications of devices include thrombosis, infections or prosthetic valve failure and interaction with their manufacturers is important.

Fetal and pediatric cardiology, pediatric cardiac surgery and adult congenital heart disease are likely to be part of the clinical service in tertiary centers. Knowledge of anatomy and pathology of congenital heart disease is highly valuable (Table 17). Expertise in handling and interpretation of diagnostic endomyocardial biopsy is expected (Table 18), as well as expert knowledge of genetic cardiovascular disorders (Table 19). The study of sudden death (Table 20) requires specific expertise. A “molecular autopsy” is frequently indicated, particularly in the young, where 30–40% of cases

Table 10  
Level 1

Cerebral vascular disease
Cerebral hemorrhage
Subarachnoid (berry aneurysm rupture)
Intraparenchymal bleedings
Cerebral infarct
Embolism
Left atrial appendage thrombosis
Ventricular mural thrombosis
Endocardial tumors
Proximal aortic and carotid arteries atherothrombosis
Paradoxical embolism with patent foramen ovale
Carotid/Cerebral artery obstructive disease

Table 11  
Level 1

Sudden death
Non-cardiac
Cerebral
Respiratory
Cardiac
Mechanical (pulmonary embolism, hemopericardium due to heart or aortic rupture)
Arrhythmic
Ischemic
Non ischemic (with or without structural abnormalities)
Vascular rupture (hemorrhagic shock)

have a genetically determined cause. Cardiovascular Pathologists are well positioned to play a major role in the molecular autopsy. The pathologists may examine the heart, ensure adequate tissues are referred for the molecular analysis, and then, most importantly, aid in integrating the morphological and molecular results. Last, but not least, transplant pathology is a fundamental expertise, both in terms of endomyocardial biopsy monitoring for acute rejection and the evaluation of complications in explanted allografts (Table 21).

Modern cardiovascular medicine requires a cardiovascular pathologist to use a range of molecular methods on biopsy and autopsy material. Nucleic acid extraction for identification of viral infection in the myocardium (myocarditis) or genetic polymorphisms or mutations in nucleic acids from blood samples or tissue are especially important. To facilitate referrals from other centers protocols on the selection and preservation of these samples should be forwarded to referring institutions. Few, if any, Level 3 centers will have the full range of electron microscopic and confocal techniques, molecular and genetic methods at hand. Material for these specialized investigations may be sent to

Table 12  
Level 1

Valvular heart disease
Aortic
Annulo-aortic ectasia
Calcific degeneration (senile, bicuspid valve)
Endocarditis (infective, non-bacterial thrombotic)
Rheumatic
Mitral
Annular dilatation
Calcification of the mitral annulus
Chordal rupture
Endocarditis (Infective, non-bacterial thrombotic)
Myxomatous degeneration
Papillary muscle rupture and fibrosis
Rheumatic
Tricuspid/pulmonic
Annular dilatation
Carcinoid valvular disease
Endocarditis (infective, non-bacterial thrombotic)
Rheumatic
Valve repairs

Table 13  
Level 1

Effects of drugs on the heart
Alcohol
Cocaine
Anabolic steroids
Fenfluramine/phentermine
Anthracyclines
Chloroquine
Others

specialized referral centers. What is crucial is the ability of the Level 3 cardiovascular pathologist to identify the need for these investigations and to evaluate their results.

A bank of frozen, fixed, and embedded tissue may be formed in accordance with local, regional or national standards for patient consent and privacy. If organ retention is permitted, it is an invaluable resource for diagnosis, research, and teaching purposes. An electronic database of gross specimens and tissue samples is invaluable for teaching and research purposes. It is possible that the biobank may also store samples such as blood, plasma, and urine, collected by standard protocols in the context of collaborative studies and trials.

We stress that the success of a centre of excellence in cardiovascular pathology requires close collaboration with colleagues with Level 1 and 2 skills in an active regional network. Our view is that a referral center in cardiovascular pathology with Level 3 expertise should be available for every 4–5 million inhabitants, although it is recognized this is an ideal expectation. When there are competing demands we suggest that Level 3 cardiovascular pathologists may be in a strong position to contribute to pulmonary or renal pathology services. The support of well-trained laboratory

Table 14  
Level 2

Interventional and surgical prostheses/devices
Closure devices
Intraortic balloon pump
Prosthetic valves
Bioprostheses
Autografts
Homografts
Xenografts, porcine aortic valve or bovine pericardial (stented, unstented)
Mechanical prostheses—Ball, tilting disc, bi-leaflet valves
Trans-catheter valve implantations
Complications
Calcification and tearing
Thrombus
Fibrous pannus
Leaflet wearing, stent fracture, and poppet escape
Paravalvular leak
Endocarditis
Stents (thrombosis, restenosis) and embolic protection devices
Vascular grafts and stent-grafts
Pacemaker and implantable cardioverter defibrillator
Left ventricular assistance devices and total artificial hearts

Table 15  
Level 2

Surgical pathology
Aorta
Endarterectomy
Lung
Myocardium
Pericardium
Valves
Vessels
Tumors/masses

scientists or technical assistants is, as in all areas of pathology, essential.

A full time Level 3 cardiovascular pathologist requires complete training in anatomic pathology and significant experience in a Level 3 cardiovascular pathology service. We suggest a minimum of 6 months training in cardiovascular pathology. If a significant academic research career is contemplated, additional training time for adequate exposure to research methods, grant preparation and writing would be recommended. Wherever possible, a formal fellowship programme should be established. During this period, the trainee should acquire a working knowledge of clinical physiology and electrophysiology, angiography and clinical imaging, cardiac surgery and interventional techniques, and relevant molecular methods. Although knowledge of clinical procedures and decision making may be acquired through attendance at rounds and clinical cases conferences, a period of cardiovascular clinical training is advantageous. Interaction with clinical colleagues is both an important part of the cardiovascular pathologist's continuing education and is optimal for patient care. It is important that cardiovascular pathologists share the same interdisciplinary common language as the clinicians.

Teaching at the undergraduate and postgraduate level is an important and essential part of the work of a Level 3 cardiovascular pathologist. Continuing medical education of other pathologists and clinicians is also an important role. Particular emphasis should be placed on pathological and cardiovascular anatomy and cardiovascular pathophysiology. Interaction with medical examiners, coroners, and other members of the legal profession is frequently of considerable importance.

Because research is an integral part of the work of a Level 3 cardiovascular pathologist, she/he should be

Table 16  
Level 3

Conduction system disease/arrhythmias
Histologic substrates of:
Sino-atrial block
Atrioventricular block
Bundle branch block
Pre-excitation syndromes
Ablation lesions

Table 17  
Level 3

Congenital heart disease (CHD)
Normal in utero blood flow and changes with birth
CHD with septal defect and left-to-right shunt [anomalous pulmonary venous drainage, atrial septal defect, ventricular septal defect, atrioventricular (AV) canal, truncus, patent ductus arteriosus]
CHD with septal defect and right-to-left shunt (tetralogy of Fallot, pulmonary stenosis + atrial septal defect)
CHD with right or left obstruction (aortic stenosis, pulmonary stenosis, isthmal coarctation)
Transposition, complete and corrected
Hypoplastic right or left heart (aortic atresia, pulmonary atresia, mitral and tricuspid atresia)
Univentricular hearts (double inlet ventricles)
Ebstein anomaly, mitral valve anomalies
Eisenmenger syndrome
Operated CHD, including multi-stage operations

proficient with preparation of grant applications and in writing manuscripts, both in a primary and a collaborative role. Training programmes should emphasize the skills required to produce authoritative diagnostic reports, research proposals, scientific papers, and reports to industrial collaborators and lay organizations.

## 5. Medical expertise and roles—comments

In tertiary centers all highly specialized pathologists have important interactions with patients, colleagues, other health care professionals, and academics and policy experts from diverse disciplines. This is especially important for cardiovascular pathologists. Although we are a small subspecialty, we work in a rapidly advancing field which consumes a large proportion of health care budgets in all parts of the world. It is important that trainees have an appreciation for the complexity of these related clinical and scholarly roles.

In Canada, these roles are known as the Royal College of Physicians and Surgeons of Canada CANMEDS roles. A more complete discussion may be found at the website <http://rcpsc.medical.org/canmeds/index> [8]. In brief, the cardiovascular pathologist is a communicator, a collaborator, a leader,

Table 18  
Level 3

Endomyocardial biopsy
Indications
Myocarditis and dilated cardiomyopathy
Infiltrative and storage diseases
Arrhythmic diseases
Cardiac tumors
Others
Complications
Adequacy and tissue handling
Immunohistochemistry
Electron microscopy
Molecular diagnostics

Table 19  
Level 3

Genetic cardiovascular disorders
Dilated cardiomyopathy
Hypertrophic and restrictive cardiomyopathy
Arrhythmogenic right ventricular cardiomyopathy/dysplasia
Duchenne and Becker muscular dystrophy
Mitochondrial cardiomyopathies
Marfan syndrome
Channelopathies (long and short QT, Brugada syndrome, catecholaminergic ventricular tachycardia)
Non-compacted myocardium
Others

a manager, a health advocate, a scholar and a professional at the intersection of many disciplines (Table 22).

Through effective communication, cardiovascular pathologists facilitate the doctor–patient relationship and the exchanges that occur before, during, and after the medical encounter. They convey relevant information and explanations to colleagues, other professionals and on a more than occasional basis directly to patients and their families. Through these collaborations, cardiovascular pathologists effectively work within a healthcare team to achieve and advance optimal patient care. Collaborating and communicating with colleagues strengthens knowledge and facilitates diagnostic excellence. As molecular and genetic diagnoses evolve this collaboration can only increase. Cardiovascular pathologists are encouraged to participate actively in hospital management and clinical governance. Because they act as a bridge between the laboratory and the bedside, they are uniquely placed to influence decisions on the allocation of resources to cardiovascular medicine in its broadest sense. As advocates of public health, cardiovascular pathologists use their expertise and influence to advance the health and well-being of individual patients, communities, and populations. They are important advocates for the importance of post-mortem examinations. As scholars, cardiovascular pathologists pursue a lifelong commitment to reflective learning. They have key roles in the creation,

Table 20  
Level 3

Sudden cardiac death (referral)
Coronary artery congenital anomalies
Coronary atherosclerosis
Coronary artery dissection
Myocarditis—lymphocytic/viral, hypersensitivity, giant cell
Hypertrophic cardiomyopathy
Idiopathic left ventricular hypertrophy/fibrosis
Arrhythmogenic right ventricular cardiomyopathy
Aortic valve stenosis
Mitral valve prolapse
Aortic dissection
Conduction system disorders (AV block, Wolff-Parkinson-White syndrome)
Sudden unexplained death syndrome

Table 21  
Level 3

Transplant pathology
Endomyocardial biopsy monitoring
Acute rejection (cellular, humoral)
Acute cellular rejection
Antibody mediated rejection
Allograft vasculopathy (graft vascular disease in heart and other allografts)
Other findings
Quilty effect
Ischemic injury
Infections
Post-transplant neoplasms
Lymphoproliferative disorders

dissemination, and translation of medical knowledge. Through ongoing learning and critical evaluation they can influence the clinical practice of other pathologists and the practice of many clinical colleagues. Finally, as professionals, cardiovascular pathologists are committed to the health and well being of individuals and society through ethical practice, profession-led regulation and high personal standards of behavior.

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Table 22  
All levels

Diversity of the roles played by the cardiovascular pathologist as a medical expert
Communicator
Collaborator
Manager
Leader
Health advocate
Scholar
Professional

See CANMEDS roles, <http://rcpsc.medical.org/canmeds/index>.