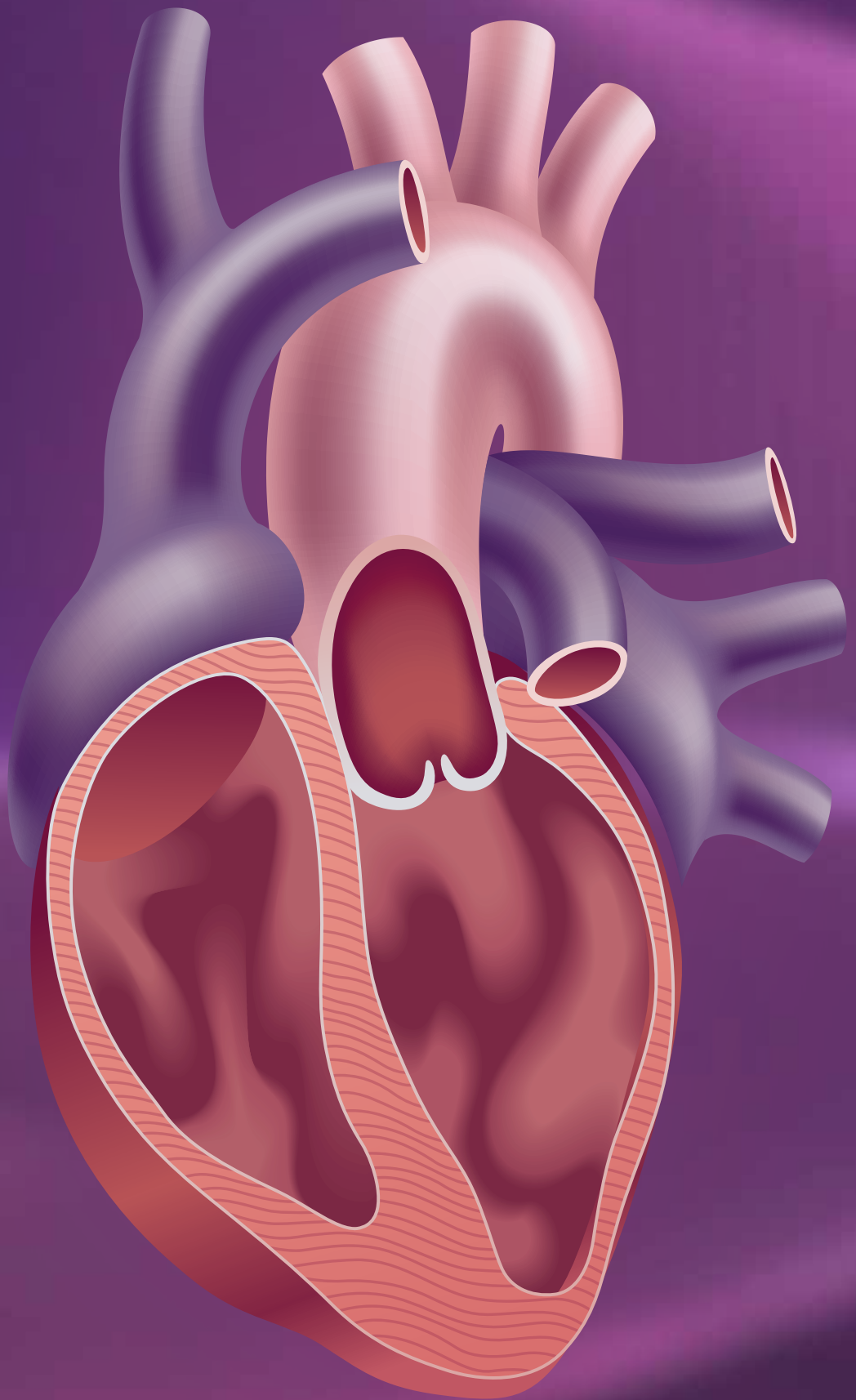

The Ross Procedure: Cardiac Autograft and Allograft

Part 1 of 2

Kevin B. Frey, CST, FAST

The Ross procedure has a history of fluctuating popularity over the years, but due to recent studies providing data on long-term survival rates that attest to the durability of the pulmonary valve (PV), the number of procedures is climbing again.[1] The procedure has proven to be free from valve-related complications and restore an excellent quality of life to patients. The procedure has proven to be free from valve-related complications and restore an excellent quality of life to patients.

The increase in performing the procedure is attributed to improving and modifying the surgical techniques in stabilizing the autograft root at the annulus, sinotubular junction, and sinus of Valsalva. This article provides the details of the procedural steps, a discussion of factors that support a successful procedure, and a review of the recent studies showing that the procedure provides excellent long-term results for the patient.

INTRODUCTION

The Ross procedure, also known as the switch procedure, that involves replacing the diseased aortic valve (AV) with the patient's own healthy PV was developed by and first performed by the British surgeon, Dr. Donald Ross, in 1967 (he also led the surgical team at the National Heart Hospital in London in performing the United Kingdom's first

LEARNING OBJECTIVES

- Identify the relevant anatomy.
- Recall the indications and contraindications for the procedure.
- Describe the technical aspects of the procedural steps.
- Evaluate the factors that contribute to good patient outcomes.
- Discuss the results of studies that confirm long-term positive results.

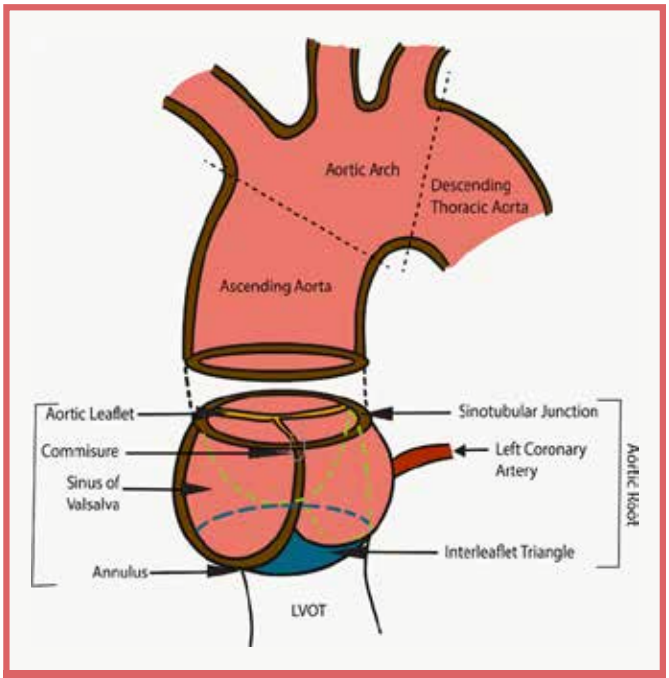

Figure 1: Aortic root anatomy.
(https://insightsimaging.springeropen.com/articles/10.1186/s13244-020-00855-w/figures/2)

heart transplant in 1968).[2,3] An allograft PV is used to replace the patient's native PV. The procedure was initially popular reaching its peak in the 1990s, but was followed by a significant decrease in usage because of its technical complexity, lack of long-term durability, and controversy that it transforms a one-valve procedure into a two-valve procedure.[2,4] While it is a technically demanding procedure that does take longer to perform as compared to a one-valve procedure, in the last decade it has been demonstrated to be the only operation that restores life expectancy similar to that of the general population with excellent quality of life, long-term outcomes, and low rates of valve-related complications.[1,2,4] Other advantages of the procedure include:

- low risk of thromboembolism,[5]
- autograft PV grows as a pediatric patient grows,
- excellent hemodynamic performance at rest and during exercise,[6]
- eliminating the need for lifelong anticoagulation medicine because biological valves are used,[5]
- quality of life is comparable to the population that has not undergone aortic valve replacement (AVR),[5] and
- allograft PV typically lasts 15 – 20 years because of the lower pressures on the right side of the heart that places less stress on the PV.[7]

The goal of the procedure is to implant a PV autograft into the left ventricular outflow tract (native aortic root) that has normal anatomic symmetrical shape and physiologic function with valve cusps and commissures the open and close normally, mimicking a normal aortic valve.

REVIEW OF ANATOMY AS RELATED TO THE ROSS PROCEDURE

The first step in understanding the Ross procedure is knowing the surgical anatomy. It is critical for the CST to understand the surgical anatomy to be able to fully prepare for the procedure including the equipment, instruments, and supplies that will be needed for the procedure as well as being able to anticipate the needs of the surgical team. This contributes to the long-term success of the procedure for the patient.

The anatomical focus of the procedure is on the aortic root. The aortic root is a small section with an average diameter of 3.0 cm that connects the heart to the circulatory system. It consists of the AV leaflets, the leaflet attachments, the sinotubular junction (STJ), the sinuses of Valsalva, the interleaflet triangles (trigones), and the annulus (Figure 1). The AV sustains a good amount of force and pressure as all the oxygenated blood that enters the circulatory system exits the left ventricle passing through the AV into the ascending aorta (Figure 2). Three leaflets, also called semilunar cusps, form the tricuspid AV; anatomically, the valve leaflets are divided into three parts.

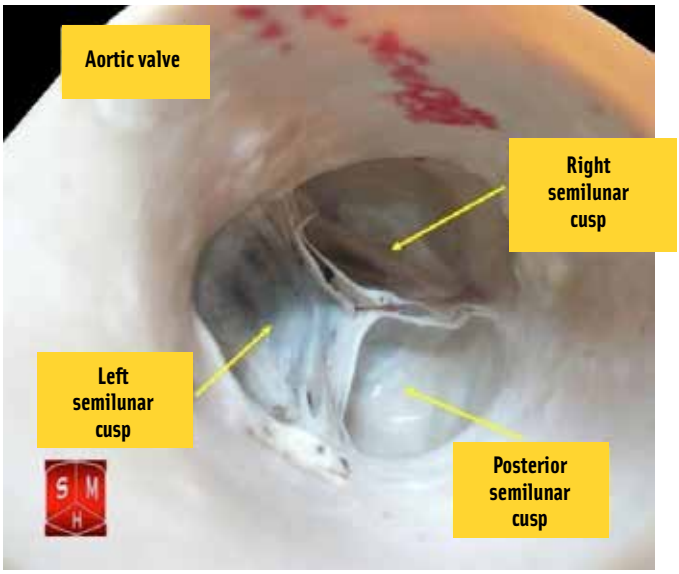

Figure 2: Aortic valve located centrally between the ascending aorta and LVOT.
(Anatomist90, Public Domain, via Wikimedia Commons)
(To view video clip of valve movement, go to https://www.ncbi.nlm.nih.gov/books/NBK558939/figure/article-617.image.f2/)

The anatomical focus of the procedure is on the aortic root. The aortic root is a small section with an average diameter of 3.0 cm that connects the heart to the circulatory system.

- Free margin that provides the coaptation area to ensure proper alignment and function of the leaflet with the other leaflets. The thickened circular node called the nodule of Arantius is in the center of the free margin.[8] It helps to stabilize and guide the closure of the valve to prevent prolapse as well as serves as a point of attachment of the tendinous cords to connect the valve to the papillary muscles of the left ventricle.[8]
- The main portion of the leaflet.
- The leaflet attachments.

Where the leaflet attachments insert in the wall of the aortic root, they form a thick fibrous structure called the annulus. The commissures are the points where the leaflet attachments run parallel towards the ascending aorta.[8]

The three aortic wall prominences are the sinuses of Valsalva, named after the 18th century Italian anatomist Antonio Valsalva. Two of the three sinuses are the origin of the coronary arteries; therefore, the sinuses are named respectively the left, right, and non-coronary sinus.[8] At the bases of sinuses, the ventricular musculature is partially involved. The walls of the sinuses predominantly consist of aortic wall, but the wall is thinner as compared to the aorta itself.

Posterior to each commissure is one of the three interleaflet triangles also called trigones. Histologically, they consist of thin aortic wall, but hemodynamically they are an extension of the left ventricular outflow tract (LVOT) and extend to the level of the STJ in the area of the commissures.[8]

The tubular structure from the distal portion of the sinuses toward the ascending aorta combined with the commissures is the STJ. It separates the aortic root from the ascending aorta. In some patients, dilatation of the STJ is the cause of central aortic insufficiency and replacing the ascending aorta with a short tubular graft restores the valve competence.[8]

KEYWORDS & DEFINITIONS

KEYWORDS:
Allograft (homograft), annulus, aortic regurgitation, aortic root, aortic stenosis, aortic valve replacement, autograft, coaptation, coronary button, decellularized cryopreserved allograft, infundibulum, left coronary artery, left ventricular outflow tract, nadir, native, pulmonary valve, sinotubular junction, sinus of Valsalva.

DEFINITIONS

Adventitial tissues: outer layer of connective tissue that surrounds organs to bind them to surrounding tissues and provide support.

Allograft (homograft): Tissue or organ transplanted from a donor of the same species, but different genetic makeup.

Aortic regurgitation: Disease where the aortic valve improperly closes, allowing blood to flow backwards from the aorta into the left ventricle. Common causes are endocarditis, dissection of the ascending aorta, and Marfan syndrome.

Autograft: Patient's own (autologous) tissue or organ, called that is transplanted from one part of the body to another.

Coaptation: Bringing two anatomical structures or surfaces together to ensure proper alignment and function.

Coronary button: Small-full-thickness section of aorta surrounding the coronary artery ostia (opening). In the Ross procedure, preserved to later reattach to the artery.

Decellularized cryopreserved allograft: Human heart valve treated to remove all donor cells while preserving the valve's structure.

Infundibulum: Funnel-shaped portion of the right ventricle that opens into the pulmonary artery; also called the conus arteriosus.

Nadir: Also called the hinge point, the nadir of a cusp refers to the point where the cusp is attached to the left ventricular outflow tract. The nadirs of the three aortic valve cusps form the annulus.

Native: Tissue or organ that is not prosthetic; body's original tissue.

Septal perforator arteries: Small arteries that branch off the left anterior descending artery and supply blood to the interventricular septum. Injury to the arteries can lead to arrhythmias and ischemia. The anatomy must be understood when performing cardiac procedures such as aortic valve replacement.

Sinotubular junction: Region of the ascending aorta between the aortic sinuses of Valsalva and where the normal tubular structure of the aorta is attained. The superior attachments of the aortic valvular leaflets establish the level of the junction.

Sinuses of Valsalva: Three anatomical outpouchings in the aortic root located between the aortic valve annulus and sinotubular junction. They help to prevent the aortic valve cusps from touching the inner surface of the aorta and obstructing the openings of the coronary arteries during systole.

The definition of annulus is a ring or circular shaped object or structure. However, when applied to the aortic root, the term is inaccurate, because the 'annulus' is more of a crown shape. However the term is used, it is the area of the smallest diameter in the circulatory route between the left ventricle and the aorta.[8] This is also an important anatomical landmark as this is the level measured by echocardiographers called the 'aortic valve annulus' to determine the size of a prosthesis to be implanted during an AVR.

Regarding the Ross procedure, it is important to know the anatomy of the left coronary artery (LCA) to understand its relationship to the aortic root (Figure 3).[7] The LCA originates from the left side of the base of the ascending aorta. Its opening is located on the dilated wall of the ascending aorta, slightly superior to the left semilunar cusp (leaflet) of the AV.[9] It travels in an anterior direction and to the left, passing between the pulmonary trunk and left atrial appendage.[9] It divides into two branches – left anterior descending artery and left circumflex artery. In 15% - 30% of patients there will be a third branch in the middle of the two other branches called the ramus intermedius.[9]

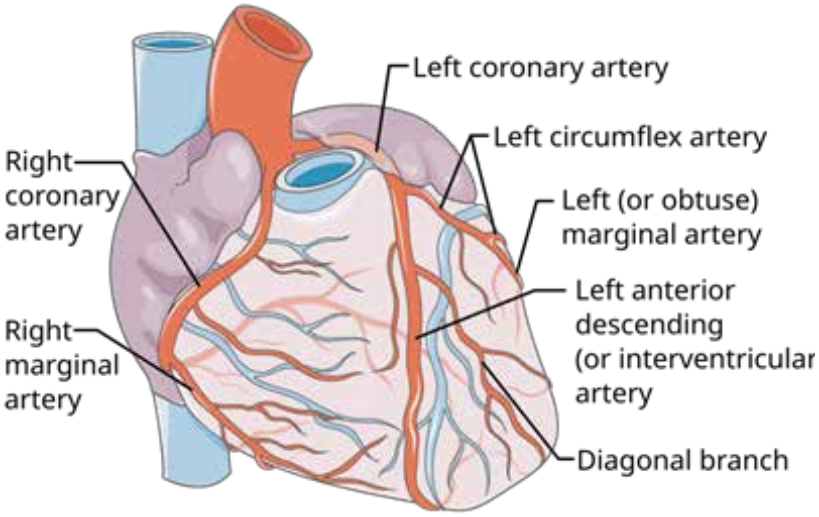

Figure 3: Coronary artery anatomy
(https://commons.wikimedia.org/wiki/File:Coronary_vessels,_with_annotated_arteries.svg)

The PV is the logical valve to use for AVR because it is an anatomical mirror image of the AV (Figure 4).[3] It is comparable in hemodynamics, allowing the patient to maintain a normal quality of life and exercise capacity. Bioprosthetic and mechanical replacement valves, when compared to the Ross procedure, are unable to fully reproduce the heart's natural hemodynamics thus causing more stress on the heart muscle. Additionally, these types of replacement valves have a significantly higher level of risk for blood clot formation and infection as well as shorter life span of functioning.[3]

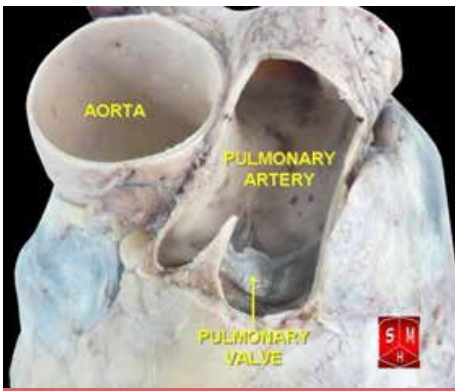

Figure 4: Pulmonary valve
(https://commons.wikimedia.org/wiki/File:Pulmonary_artery.jpg)

PATIENTS WHO ARE IDEAL CANDIDATES FOR THE ROSS PROCEDURE

The ideal patients for the Ross procedure include the following.

Adults with aortic regurgitation with a dilated aorta.

- Patient that has a life expectancy of at least 15 years.[10]
- Patients with left ventricular outflow obstructive disease.
- Severe forms of aortic valve disease that cannot be repaired.
- Pediatric patients with congenital aortic stenosis (most common indication).[7]
- Native or prosthetic valve endocarditis; however, depends on extent of the disease.[7]
- Females wanting to have children diagnosed with bicuspid aortic valve and small aortic annulus.
- Patients that have no chronic condition that may affect long-term survival such as chronic renal disease or coronary artery disease.[2]
- The ideal patient is active, healthy, and 50 years old or younger. However, active patients that are up to 65 years of age can be considered for the procedure.[10]

The reasons for the Ross procedure being ideal for pediatric patients who require an AVR are small-sized AVs are not available on the market and secondly, the prosthetic valve remains the same size as the child grows leading to left ventricular outflow obstruction.[7] In contrast, both the

autograft and allograft PV grow with the child making the Ross procedure an excellent surgical option.

Preoperatively, a transesophageal echocardiography (TEE) is performed to:

- assess the patient's aortic valve and LVOT,[7]
- rule out any other cardiovascular abnormalities, and
- assess the pulmonary valve for regurgitation and stenosis.[7] Mild pulmonary regurgitation is common and does not exclude the patient from undergoing surgery, whereas severe regurgitation will require further assessment.[4]

Additionally, the TEE allows for sizing the aortic and pulmonary annulus, the sinuses of

Valsalva, the STJ, and ascending aorta.[1] If the aortic annulus is 2-3 mm smaller than the pulmonary annulus, the patient will first have to undergo an aortic root enlargement procedure.[7]

CONTRAINDICATIONS FOR THE ROSS PROCEDURE

A patient with any of the following diseases is not eligible for the Ross procedure. These contraindications are reflective of the current American Heart Association and Canadian Cardiovascular Society valvular guidelines.[11,12]

- PV disease.
- Advanced mitral valve disease.[7]
- Radiation-induced heart disease.[10]
- Life expectancy is less than 15 years.[10]
- Advanced three-vessel coronary artery disease.[7]
- Autoimmune disorders such as lupus erythematosus and rheumatoid arthritis.
- Any type of connective tissue disorder including Loeys-Dietz syndrome (genetic tissue disorder characterized by enlarged aorta and other skeletal and craniofacial abnormalities) and Marfan syndrome.[2]

COMING NEXT

Part Two: The Ross Procedure, Part 2 will be published in the August edition of The Surgical Technologist.

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The Ross Procedure: Cardiac Autograft and Allograft, Part 1

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1. What structure do the AV leaflet attachments form in the wall of the aortic root?
A. Sinuses
B. Annulus
C. Nadir
D. Infundibulum

2. What is the cause of central aortic insufficiency that leads to replacing the ascending aorta?
A. STJ dilatation
B. Aortic regurgitation
C. Leaflet calcification
D. Endocarditis

3. Which of the following is a complication associated with the use of bioprosthetic replacement valves?
A. Does not place enough tension on heart
B. Grows to large over time
C. High risk for infection
D. Mimic's heart's hemodynamics

4. Which preoperative diagnostic test is performed to assess the LVOT?
A. TEE
B. Plethysmography
C. Angiography
D. Cardiac MRI

5. What part of the tricuspid AV is the point of attachment of the tendinous cords?
A. Main portion of the leaflet
B. Leaflet attachments
C. Nodule of Arantius
D. Free margin

6. Which of the following serves as the origin of the coronary arteries?
A. Cusps
B. Aortic root
C. Commissures
D. Sinuses of Valsalva

7. In a certain percentage of patients there is a third branch of the LCA called the _____.
A. Left circumflex artery
B. Ramus intermedius
C. Right marginal artery
D. Diagonal branch

8. Which structure separates the aortic root from the ascending aorta?
A. Leaflets
B. Trigones
C. STJ
D. Sinuses of Valsalva

9. What complication occurs with pediatric patients that receive a prosthetic valve?
A. Endocarditis
B. Aortic regurgitation
C. Coronary artery disease
D. Left ventricular outflow obstruction

10. Patients will undergo an aortic root enlargement procedure if the aortic annulus is _____ mm smaller than the pulmonary annulus.
A. 2 - 3
B. 4 - 5
C. 6 - 7
D. 8 – 9

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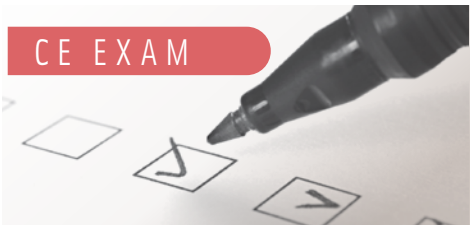

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