β-Blockers for Cardiac CT: A Primer for the Radiologist

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OBJECTIVE. The objective of this article is to describe a protocol for the administration of β-blockers for cardiac CT. A low and regular heart rate is necessary for optimal visualization of the coronary arteries on CT and can be achieved by the administration of medications.

CONCLUSION. Beta-blockers can be safely given, orally or IV, to most patients to lower the heart rate for cardiac CT. A protocol can be implemented and patients can be screened for certain contraindications to allow successful administration of these medications by radiologists.

An essential part of performing a successful CT coronary angiography examination is to optimize the patient's heart rate to limit motion artifacts in the coronary arteries. The temporal resolution of MDCT is improving, from 250 msec on 4-slice scanners to 180 msec on 64-slice scanners, but technologic limitations still require a low and regular heart rate for optimal studies. The use of β-blockers is advocated for cardiac CT studies to lower the heart rate to less than 65–70 beats per minute (bpm) and to make the rhythm more regular. With improvement in scanner technology, the heart rate range over which diagnostic studies can be obtained will likely increase.

For those patients for whom β-blockers are considered, certain guidelines are suggested to avoid complications [1]. The protocol can include oral, IV, or a combination of oral and IV administration [2]. We present our protocol for administering metoprolol, a β_1-antagonist and cardioselective β-blocker, for cardiac CT studies (Table 1). The determination to give β-blockers and the dosage to be used should be individualized for each patient on the basis of the practitioner's assessment of the patient and the patient's history and consultation with a pharmacist as necessary.

β-Blocker Administration Protocol

I: Assessing Whether β-Blocker Administration Is Necessary

On arrival in the department, the patient's vital signs are checked and pulse is noted. If the patient has a regular rhythm and the heart rate is less than 65 bpm, no β-blockers are given and the patient goes straight for CT. If the patient's heart rate is greater than 65 bpm or if the rhythm is irregular and the heart rate is greater than 60 bpm, further assessment is done to determine whether a β-blocker can be given. The nurse checks the patient's vital signs, screens him or her for β-blocker administration, administers the β-blocker, and monitors the patient, all of which is done under the supervision of the radiologist.

II: Screening Patients for Contraindications to Giving β-Blockers

Patients are screened for medical conditions that may preclude them from receiving β-blockers. These contraindications are sinus bradycardia, which is defined as a heart rate of less than 60 bpm; systolic blood pressure of less than 100 mm Hg; allergy to the medication or its constituents; decompensated cardiac failure; asthma on β-agonist inhalers; active bronchospasm; and second- or third-degree atrioventricular block. We also do not administer β-blockers to pregnant patients. Sinus bradycardia and hypotension are excluded by obtaining the patient's vital signs. The patient is then asked if he or she has known allergies or a history of asthma or chronic obstructive pulmonary disease (COPD).

Although metoprolol has relative β_1 selectivity, especially at low doses, according to the *Physicians' Desk Reference*, "patients with bronchospastic diseases, in general, should not receive beta blockers" [1]. In patients with COPD, the use of β-blockers has

Keywords: β-blocker, cardiac imaging, coronary arteries, CT arteriography, MDCT

DOI:10.2214/AJR.04.1944

Received December 22, 2004; accepted after revision March 23, 2005.

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AJR 2006; 186:S341–S345

0361–803X/06/1866–S341

TABLE 1: β-Blocker Administration Protocol

Protocol	Parameter(s)	Action(s)
Assess whether β-blockers are necessary	If pulse is < 65 bpm and regular or if pulse is < 60 bpm and irregular	A β-blocker is **not** given
	If pulse is > 65 bpm or if pulse is > 60 bpm and irregular	Screen for contraindications for giving β-blocker
Screen for contraindications for β-blockers	If any of the following conditions exist: Heart rate, < 60 bpm Systolic blood pressure, < 100 mm Hg Decompensated cardiac failure Allergy to β-blocker Asthma or COPD on β_2-agonist inhaler Active bronchospasm Second- or third-degree atrioventricular block	A β-blocker is **not** given
	If the above conditions are absent	Oral metoprolol is given
Administer metoprolol	If giving **oral** metoprolol,	One 50-mg dose of metoprolol is given orally and patient is monitored over 1 hr, during which heart rate is checked every 15 min. If heart rate remains elevated, perform practice breath-hold If heart rate still remains elevated, give IV metoprolol
	If giving **IV** metoprolol,	Two 2.5-mg doses of metoprolol are given 5 min apart; then, two doses of 5 mg each are given 5 min apart. Total maximum dose, 15 mg. Blood pressure and heart rate are checked before each IV dose
Administer postprocedure care	If only one dose of oral metoprolol is given	No monitoring necessary, patient can leave department after study
	If IV metoprolol is given	The patient is observed for 30 min
	If heart rate drops to < 45 bpm	Consideration is given to administering atropine
	If bronchospasm occurs	A β-agonist inhaler is given

Note—bpm = beats per minute, COPD = chronic obstructive pulmonary disease.

been somewhat controversial. In patients with mild COPD, the use of cardioselective β-blockers—which include agents such as atenolol, esmolol, bisoprolol, and metoprolol—has been shown to be safe [3–5]. However, the patient with severe COPD who is also dependent on the use of β_2-agonist inhalers, such as albuterol, should not receive β-blockers. Therefore, patients with asthma or COPD on β–agonist inhalers are not given β-blockers. Patients who report a history of asthma, such as childhood asthma, but no current asthma and who do not take asthma medications are given β-blockers. Lastly, patients are evaluated for possible second- or third-degree atrioventricular block by generating a single-lead ECG strip [6] (Fig. 1).

III: Administration of Oral Metoprolol

If all the contraindications to receiving β-blockers have been excluded, the patient is given one dose of 50 mg of metoprolol orally to lower the heart rate. The patient is monitored over 1 hr, and the heart rate is checked every 15 min. If after 60 min the patient's heart rate remains above 65 bpm, a practice breath-hold is done for 15 sec to see if there is any alteration in the heart rate. If the heart rate remains greater than 65 bpm or if the heart rate is irregular and greater than 60 bpm, further assessment is done to determine whether an IV dose of a β-blocker can be given.

IV: Precautions for Administering IV Metoprolol

IV β-blockers are given with caution if the patient has mild COPD and is being treated with oral steroids but is not using β-agonist inhalers. Caution is also used for patients who are on other atrioventricular nodal blocking agents such as calcium channel blockers (e.g., diltiazem, verapamil), digoxin, and other β-blockers. However, if the heart rate is not in the desired range, consideration is given to administering β-blockers.

V: Administration of IV Metoprolol

The patient is initially given one 2.5-mg dose of metoprolol IV over 1 min. If the heart rate remains more than 65 bpm after 5 min, a second dose of 2.5 mg of metoprolol is given. If the heart rate continues to remain elevated, up to two additional doses of 5 mg each of metoprolol can be given IV, each over 1 min, with a 5-min interval between doses. The patient's blood pressure and heart rate are checked before each dose is administered. The maximum total dose of metoprolol given is 15 mg IV with the sequence being 2.5, 2.5, 5, and 5 mg at 5-min intervals.

VI: Postprocedure Care

After the CT examination, all patients who are given IV or two oral doses of metoprolol are observed for 30 min. If the patient has bronchospasm, two puffs of an albuterol inhaler are given from a 17-g albuterol inhaler canister. If the patient's heart rate drops to less than 45 bpm, consideration is given to administering atropine. If the patient is atropine-resistant and has a low heart rate, resuscitative measures and administration of IV β_1-agonists such as dopamine or epinephrine may become necessary.

Discussion

The protocol described for administering metoprolol for cardiac CT was designed on the basis of medical experience with β-blockers, which are routinely used clinically in their oral and IV forms [1]. An algorithmic approach for giving β-blockers for cardiac CT has also been previously described [2]. Clinically, higher doses are usually given orally

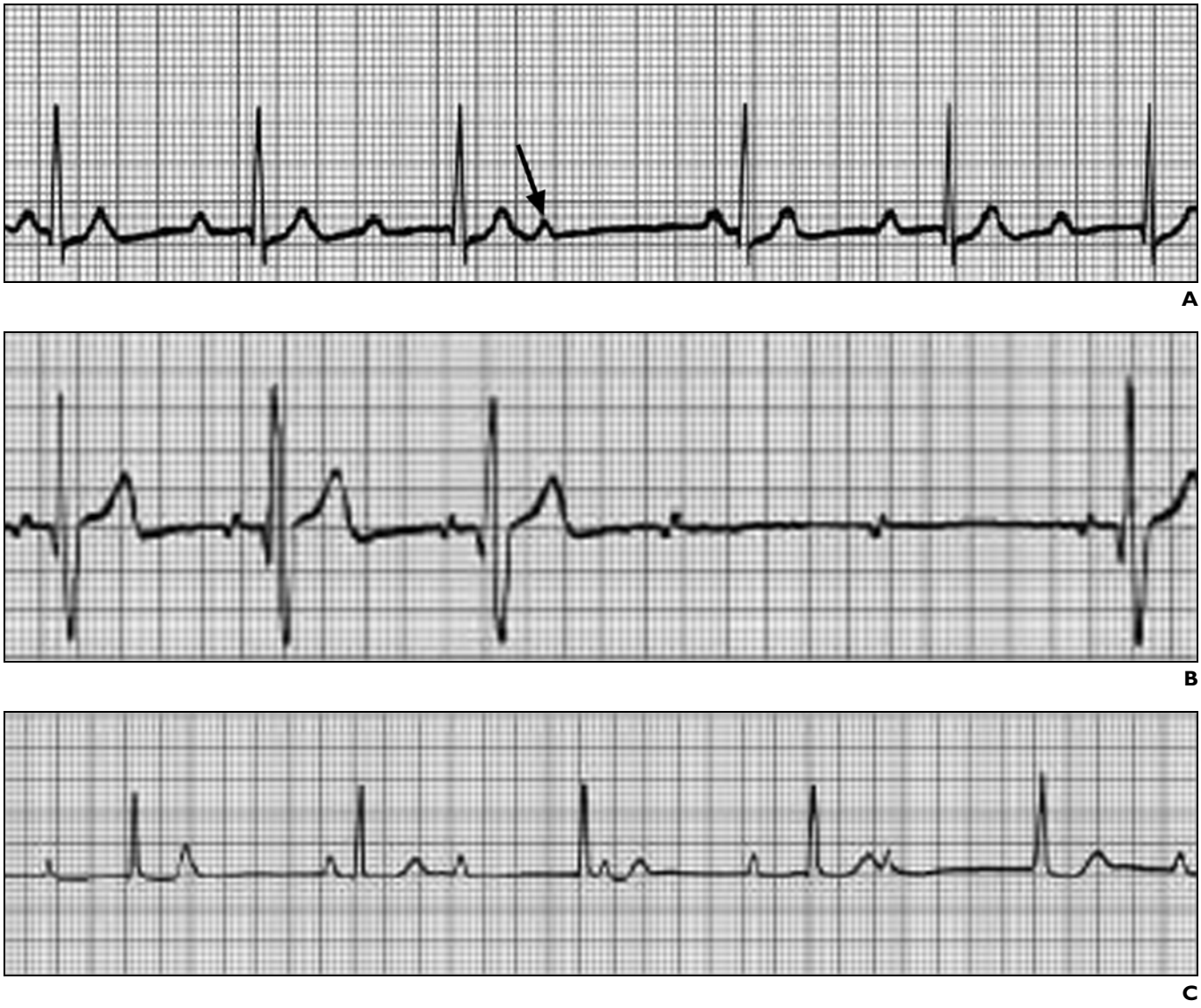

Fig. 1—ECG lead strips. (Reprinted with permission from *ACLS Provider Manual*, © 2001, 2002 American Heart Association [19])
A, Second-degree heart block, type I. There is progressive lengthening of P-R interval until QRS complex is dropped. Arrow indicates P wave, which does not have accompanying QRS.
B, Type II (high block). Regular PR–QRS intervals occur until there are two dropped beats.
C, Third-degree atrioventricular block. There is no relationship between P waves and QRS complex. There is junctional escape pacemaker giving narrow QRS.

and the IV dose is given in shorter time increments for the treatment of myocardial infarction, angina, and tachycardia [1]. Several cardioselective β-blockers exist with their own pharmacokinetic profiles (Table 2). The selection of metoprolol was based on ease of administration, readily available dosage form, cardioselectivity, and familiarity with its use.

An essential part of performing a successful CT coronary angiography examination is to limit the effect of cardiac motion on the coronary arteries. Normally, single-segment reconstruction is done using scan data from a single cardiac cycle to create the image, but this method is optimal only for patients with a low heart rate [7]. For those with a high heart rate, data from more than one cardiac cycle can be used to reconstruct the image; this method is called "multisegment reconstruction" [7, 8]. Typically, the data from two cardiac cycles are used, which improves the temporal resolution to gantry rotation time divided by 4. However, a drawback of using multiple cardiac cycles to reconstruct images is that the spatial resolution in the *z*-axis can decrease if the pitch is too high for the patient's heart rate because there are gaps in the acquired data [7]. Volume coverage or longitudinal resolution is compromised with multisegment reconstruction and the quality of the images may not be better [9, 10]. Therefore, lowering the heart rate with β-blockers is suggested as the preferred approach over using multisegment reconstruction [9, 11].

When comparing low heart rates and single-segment reconstructions with higher heart rates (> 65 bpm) and multisegment reconstructions, investigators found that vessel visibility was highest when the heart rate

TABLE 2: Cardioselective β-Blockers

β-Blocker		IV Availability (Dosage Form)	Onset	Duration (hr)	Plasma Half-Life	Route(s) of Elimination	Comments
Generic Name	Trade Name (name of manufacturer)						
Acebutolol hydrochloride	Sectral (Wyeth Laboratories)	No	1–2 hr	> 24 hr	3–4 hr	Hepatic, renal	Equipotent metabolite is diacetolol
Atenolol	Tenormin (AstraZeneca)	Yes (5 mg/10 mL)	IV, 1–2 min Oral, 1 hr	IV, 12 hr Oral, 24 hr	6–9 hr	Renal	
Betaxolol hydrochloride	Kerlone (Amide Pharmaceuticals)	No	1.5–6 hr	> 24 hr	12–22 hr	Hepatic, renal	Also available as an ophthalmic for the treatment of glaucoma
Bisoprolol	Zebeta (Wyeth Laboratories)	No	1–4 hr	24 hr	7–15 hr	Hepatic, renal	
Esmolol	Brevibloc (Baxter)	Yes (100 mg/10 mL and 2,500 mg/10 mL; no oral formulation)	1–4 min	5–10 min	4–9 min	Erythrocyte, esterase	Must use diluted form of esmolol hydrochloride (10 mg/mL); use of 2,500 mg/10 mL must be diluted to 10 mg/mL before administration
Metoprolol tartrate	Lopressor (Novartis Pharmaceuticals)	Yes (5 mg/5 mL)	IV, 5–10 min Oral, 1 hr	IV and oral, 5–8 hr	3–7 hr	Hepatic	
Metoprolol succinate	Toprol-XL (AstraZeneca)	No	2–3 hr	24 hr	3–7 hr	Hepatic	

was below 65 bpm and single-segment reconstruction was used [12]. The quality of the CT angiogram, especially for visualization of the right coronary artery, has been shown to improve with the administration of β-blockers [13]. Detection of vessel stenoses has also been shown to be higher in patients with lower heart rates [14]. The proportion of the cardiac cycle spent in diastole increases as the heart rate decreases; therefore, medications such as β-blockers are given to increase diastole [15].

In general, β-blockers are helpful in patients with irregular heart rates, as seen with premature atrial or ventricular contractions; supraventricular tachycardias; and arrhythmias, such as atrial fibrillation. There is an alternating sinus bradycardia and atrial tachycardia due to sinus node dysfunction in the tachycardia-bradycardia syndrome form of sinus node dysfunction. With atrial fibrillation, the negative chronotropic and dromotropic effects of the β-blocker lengthen the diastolic portion of the cardiac cycle. Beta-blockers can be given to patients with pacemakers if the heart rate is higher than the paced rhythm and no pacer spikes are seen in the ECG tracing. Once the pacer spikes are identified, the heart rate cannot be lowered any further.

Beta-blockers can be given for short-term use, such as for a CT study, in patients with diabetes, psoriasis, controlled congestive heart failure, and ablated Wolff-Parkinson-White syndrome. Beta-blockers can also be given for a CT study to patients who are on medications such as reserpine, monoamine oxidase (MAO) inhibitors, clonidine, quinidine, fluoxetine, paroxetine, and propafenone. For patients who are on long-term treatment with β-blockers, reserpine and MAO inhibitors can have an additive effect, and the serum concentration can be increased if quinidine, fluoxetine, paroxetine, and propafenone are also present. Less than 1 mg of metoprolol is excreted per liter of breast milk and breast feeding may be held for 12 hr after administration [16].

After a single oral dose of metoprolol, plasma levels of metoprolol are detectable at 10 min. The effects of an oral dose are seen within 1 hr after administration. Peak plasma concentrations are seen at 90 min. Plasma concentrations of metoprolol after an IV dose are approximately twice that seen with the oral route of administration. The peak effect of IV-push metoprolol occurs between 5 and 10 min after administration. The plasma half-life for oral and IV metoprolol in healthy volunteers ranges from 3 to 4 hr [16].

Although β-blockers can help lower the heart rate, they also have a negative inotropic effect and can decrease left ventricular contractility [17, 18]. This may impact assessment of ventricular function; however, currently ventricular contractility is typically evaluated by echocardiography or nuclear medicine studies and the role of CT is primarily to assess the coronary arteries.

Conclusion

High-quality diagnostic images are most likely to be produced from a CT coronary angiogram if the patient has a low and regular heart rate. Beta-blockers can be safely administered to most patients for a successful CT coronary angiography examination. As radiologists become more involved with cardiac CT, a detailed understanding of the techniques needed for study optimization becomes critical. The use of β-blockers is a critical part of study optimization.

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