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The Effects of Lidocaine on Reperfusion Ventricular Fibrillation During Coronary Artery – Bypass Graft Surgery

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1. Introduction

Myocardial protection with cardioplegia has resulted in significant improvement in the outcomes of cardiopulmonary bypass (CPB) in coronary artery - bypass graft (CABG) procedure. However, subendocardial damage created by ischemic injury still remains a source of morbidity and mortality associated with CABG (1). Ventricular fibrillation (VF) occurring after releasing of aortic cross-clamp in the reperfusion phase of CABG surgery (reperfusion VF) is very common (74-96 %) (1-5). This complication is considered to be related with ischemia-induced increases in reentry and automaticity as well as the possibility of reperfusion injury (6-8). Reperfusion VF may adversely affect coronary blood flow and increase ventricular wall tension, which causes a further depletion of myocardial energy reserves in an energy-depleted myocardium (2). It is estimated that reperfusion VF occurs as a result of increased myocardial wall stress and oxygen consumption besides diminished subendocardial blood flow and intramyocardial acidosis (9-12). Additional myocardial injury following defibrillation by direct current countershocks may worsen this situation (13,14). Therefore, it would be helpful for the patients' recovery after the CABG (15).

VF developing in reperfusion phase of CPB generally responds to defibrillation. Obstinate or recurrent VF increases myocardial oxygen demand, unfortunately resulting in ventricular dilatation. Furthermore, the ventricular relaxation creates irreversible myocardial injury. When heart remains in VF, it is necessary to recheck blood gases, electrolytes, and temperature. Lidocaine, a class Ib antiarrhythmic, is administered at a dose of 1 to 2 mg kg⁻¹ before repeated direct current defibrillation is attempted. Occasionally, beta blockers such as esmolol and metoprolol, class II antiarrhythmics and amiodarone, a class III antiarrhythmic are added in order to treat intractable VF or ventricular tachycardia (16). A previous study reported that in patients with persistent VF during weaning from CPB in cardiac surgery for heart diseases with left ventricular hypertrophy, amiodarone was a reasonable option (17).

Lidocaine, which is a local anaesthetic in amid group, acts as an antiarrhythmic agent and it is classified in class Ib. By binding Na⁺ channels, lidocaine alters membranous conductivity

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of cations. Lidocaine decreases depolarisation plateau of phase 4 and enhances diastolic electrical flow threshold in Purkinje fibers (18,19). Lidocaine increases VF threshold, but this effect is directly related with plasma concentrations of lidocaine (20).

Although lidocaine is known to reduce VF incidence and defibrillation demand, the mechanism is not clearly understood yet. However, it is proved to be appropriate in the treatment of ventricular ectopic premature beats (18-21). In myocardial ischemic conditions, lidocaine has been shown to turn unidirectional blocking zones and slow conduction in ischemic zones to complete blocking areas (22). Another possible mechanism could be explained by inhibitory effect of lidocaine on Na^+ intake and membrane depolarisation such that cardiac arrest occurs when they are inhibited (23). As a result, the energy is kept away from electromechanical activity thus proceeding more accurate recovery for the heart. In addition to that local anaesthetics, lidocaine can block slow Ca^{++} channels and Ca^{++} channels of sarcoplasmic reticulum (24,25).

Lidocaine has previously been added to cardioplegic solutions in order to prevent reperfusion VF (see table 1). When 500 mg L^{-1} of lidocaine was added to a crystalloid solution, there was a significant decrease in the incidence of VF, but a higher percentage of atrio-ventricular (AV) block was also observed (4-12,14,26). Baraka et al. (13) showed that the incidence of reperfusion VF can be markedly reduced, from 93% to 42%, with the addition of 100 mg L^{-1} of lidocaine to a crystalloid cardioplegic solution without an increase of the incidence of AV block. Wallace and Baker (2) repeated a similar study and reported that the incidence of reperfusion VF is reduced from 63 % to 42 % with the addition of 100 mg L^{-1} of lidocaine to a crystalloid cardioplegic solution. They noted that a higher proportion of the patients who developed reperfusion VF with lidocaine cardioplegia underwent spontaneous defibrillation (30% versus 11%), even though this was not statistically significant. On the other hand, different from the above mentioned study (13), they stated that the incidence of AV block necessitating ventricular pacing to separate from CPB was significantly higher in the lidocaine treated group (44%) as compared with the control group (20%). Sellevold et al. (27) added procaine instead of lidocaine in cardioplegic solutions to be able to observe the efficiency in post-ischemic rhythm disturbances, and they showed that cardioplegia with procaine (1 mM) stabilised post-ischemic arrhythmia without any reverse effect.

Meta-analyses suggested that prophylactic lidocaine use reduces VF but increases mortality rates after acute myocardial infarction. Although its use may not be associated with increased mortality rates, the prophylactic lidocaine use, in fact, has decreased with the advent of thrombolysis, and the routine use of prophylactic lidocaine in acute myocardial infarction is not recommended (28,29). In another study, lidocaine appears to be effective in converting no more than 20% of stable ventricular tachycardias (30).

In some investigations, the possible effect of lidocaine on autonomic cardiac control in humans was studied. Aidonidis et al. (31) found that in anaesthetized dogs, there was marked attenuation of cardiac sympathetic nervous activity by lidocaine which slightly altered efferent cardiac sympathetic nervous activity in the course of acute myocardial ischemia and reperfusion, but significantly increased it during VF. Abramovich et al. (32) showed that lidocaine has a consistent and significant parasympatholytic effect on the human heart in healthy volunteers as well as in patients in the acute phase of myocardial infarction.

Authors	Lidocaine Doses	Results
Hottenrott C et al, 1974 (9) Dahl CF et al, 1974 (14) Buckberg GD and Hottenrott CE, 1975 (10) Hearse DJ, 1977 (8) Murdock D et al, 1980 (6) Kaplinsky E et al, 1981 (7) Tchervenkov CI et al, 1983 (4) Tchervenkov CI et al, 1983 (26) Khuri SF et al, 1985 (11) Lockermen ZS et al, 1987 (12) Fiore AC et al, 1990 (5)	500 mg L ⁻¹ (in the cardioplegic solution)	Decreasing in the incidence of VF with higher percentage of AV block than the control group
Baraka A et al, 1993 (13)	100 mg L ⁻¹ (in the cardioplegic solution)	Decreasing in the incidence of VF without any increasing the incidence of AV block group
Wallace SR and Baker AB, 1994 (2)	100 mg L ⁻¹ (in the cardioplegic solution)	Decreasing in the incidence of VF without any increasing the incidence of AV block
Praeger IP et al,1988 (41)	200 mg in bolus (before aortic declamping)	Decreasing in the incidence of VF
Kirlangitis J et al, 1990 (40)	2 mg kg ⁻¹ in bolus (before aortic declamping)	Decreasing in the incidence of VF
Landow L et al, 1990 (42)	1.5 mg kg ⁻¹ in bolus with 2 mg min ⁻¹ infusion rate (before aortic declamping)	No malign dysrhythmia
Juneja R et al, 1993 (43)	1.5 mg kg ⁻¹ in bolus with 2 mg min ⁻¹ infusion rate (before aortic declamping)	Nondecreasing in the incidence of VF in patients with poor left ventricular function
Rinnie T and Kaukinen S, 1998 (44)	Continuous infusion for 20 hours with a bolus dose (before aortic clamping)	Nondecreasing in the incidence of VF
Baraka A et al, 2000 (15)	100 mg in bolus (before aortic declamping)	Decreasing in the incidence of VF with higher percentage of AV block than the control

Table 1. The results of the studies about lidocaine use to reperfusion VF

Despite the theoretical advantages of lidocaine for the treatment of VF in the cardiopulmonary resuscitation, it is well recognized that lidocaine can increase defibrillation threshold (33-36). Lidocaine has not been considered to have a substantial value in the

majority of cases of VF because of not only its potential to increase the defibrillation threshold, but also its negative inotropic activity. Its use is probably best reserved for cases of persistently recurring VF after electrical defibrillation, particularly in association with reperfusion occurring after heart surgery (34,37,38).

Hottenrott et al. (9) showed the augmentation of coronary blood flow to a sufficient rate towards increased energy demand in normal heart and in normothermic condition. They reported that redistribution occurs to keep endocardial / epicardial blood flow proportion. However, in hypertrophied and distended hearts and if a low aortic perfusion pressure exists, coronary blood flow will not be enough to meet increased oxygen consumption and this aspect can be explained by showing diminished coronary sinus pH, increased lactate levels and K^+ concentrations. In patients with severe coronary artery stenosis, the occurrence of VFs aggravates subendocardial ischemic injury in deteriorated left ventricle.

Khuri et al. (11) reported the adverse effect of VF despite venting of heart and hypothermic conditions in reperfusion state of CPB, using continuous intraoperative intramyocardial pH monitoring technique.

Dahl et al. (14) demonstrated myocardial necrosis due to defibrillation in dogs and they proved the relation between the width of pedals and the frequency of defibrillation on myocardial injury. If the pedals are small or the frequency is scarce between defibrillations, the intensity of injury will be greater.

Manolis et al. (39) compared the efficiency and safety of lidocaine and tocainide given intravenously in patients with arrhythmia following cardiac surgery. They found that the drugs were both efficient, and there was not any statistical difference between these two drugs. In their study, they had administered 100 mg lidocaine in bolus before 60 mg infusion for 15 minutes. The infusion had been continued in a dose of 1.4 mg min^{-1} and the blood level had been found to be $1-4 \text{ mg L}^{-1}$.

Kirlangitis et al. (40) compared the efficacy of bretylium (10 mg kg^{-1}), lidocaine (2 mg kg^{-1}) and (as placebo) saline to prevent or to reduce VF incidence during reperfusion phase after aorta declamping. VF was seen 91% with saline, 64% with lidocaine and 36% with bretylium. The need for defibrillation was found lower with lidocaine and bretylium than saline group, but among two drugs they did not find any significant differences.

Praeger et al. (41) showed that the incidence of VF was reduced to less than 33% with treatment with 200 mg of lidocaine intravenously 3 minutes before aortic declamping. In patients who had serum potassium levels that were higher than 5.1 mEq/l and treated with lidocaine before aortic declamping, the incidence of VF decreased to less than 15%.

Landow et al. (42) administered 1.5 mg kg^{-1} lidocaine in bolus with 2 mg min^{-1} infusion rate before aorta declamping. In more than 50% of the patients, lidocaine serum levels were found to be in sub-therapeutic borders, but free lidocaine levels were within therapeutic limits. During this study, they didn't realise any malign dysrhythmia. Following this study, Juneja et al. (43) performed another study using similar lidocaine doses and reported that in patients with poor left ventricular function, prophylactic lidocaine did not reduce ventricular arrhythmias after CABG surgeries.

Rinne and Kaukinen (44) studied the effect of an intravenous bolus of lidocaine given before clamping the aorta, which was followed by a continuous infusion for as long as 20 hours. They did not observe any increase in cardiac protection as evidenced by the analysis of serum troponin concentration and serum creatine kinase MB activity and by the electrocardiogram. They did not report any decrease in the incidence of reperfusion VF.

Baraka et al. (15) showed that the incidence of reperfusion VF could be significantly decreased without any increase in the incidence of AV block with the administration of a bolus of 100 mg of lidocaine by way of the pump 2 minutes before the release of the aortic cross-clamp. In this study, the better cardiac output after weaning from CPB in the lidocaine group versus the control group was noted. They suggested that the result might be explained by the significant decrease of reperfusion VF in the lidocaine group (11 % versus 70 %).

2. Conclusion

We concluded that following the CABG surgery, the incidence of reperfusion VF is quite high. During the CABG surgery, as a prophylactic measure, the administration of lidocaine at a dose of 1 to 2 mg kg⁻¹ before releasing the aortic cross-clamp can decrease the incidence of reperfusion VF. However, because of the risk of AV block with using lidocaine, we believe that in patients with persistent VF and also with left ventricular hypertrophy or dysfunction, the use of other anti-arrhythmic drugs would be more helpful for defibrillation.

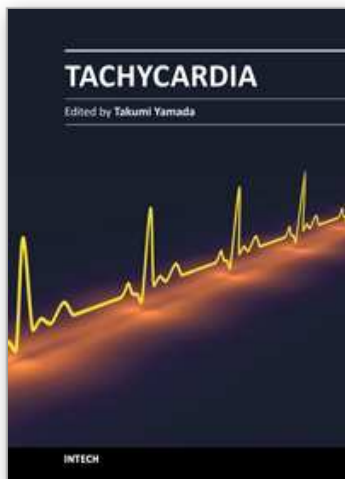
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Tachycardia

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Heart rates are normally controlled by a natural pacemaker, the sinus node, and normal heart rhythm is called sinus rhythm. Tachycardia is defined as a faster heart rhythm than normal sinus rhythm. Tachycardias can cause symptoms such as palpitations, chest pain, shortness of breath and fatigue, which reduce the quality of life. Fast tachycardias can cause hemodynamic collapse and sudden cardiac death. The causes, mechanisms, and origins of tachycardias are various. The diagnosis of tachycardias is made by electrocardiograms and electrophysiological testing. Tachycardias can be managed and treated by pharmacological and non-pharmacological approaches. This book covers these concerns from basic and clinical points of view and will lead to a further understanding and improvement in the clinical outcomes of tachycardias.

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