Title: EFFECT OF COMPRESSION RATE AND DUTY CYCLE ON CEREBRAL PERFUSION PRESSURE DURING CARDIOPULMONARY RESUSCITATION IN SWINE.

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Few studies have systematically evaluated the optimal chest compression frequency and duty cycle for cerebral perfusion during external cardiopulmonary resuscitation (CPR). Cerebral perfusion pressure (CPP) depends largely on the ability to generate cardiac output by either a direct cardiac compression pump or an intrathoracic pressure pump. If the time required to eject blood out of the pump is short and the time required for systemic and cerebral venous return is also short, then it would be advantageous to compress rapidly. If the time required to eject most of the blood out of the pump is long, then it would be advantageous to lengthen the duty cycle. The latter would hold if the intrathoracic pump with its large blood volume were important, whereas the former would hold if direct cardiac compression with its smaller volume were important[1]. We tested this in 20 kg pigs, which are commonly used in CPR models. Results were contrasted with those obtained in 5 kg piglets to model infant CPR, where direct cardiac compression may be important.

Methods. Experiments were performed on six 8 week old piglets (20 kg) and six 2 week old piglets (5 kg) anesthetized with sodium pentobarbital (30 mg/kg, iv). CPP was calculated from the difference between mean aortic and sagittal sinus pressures. Ventricular fibrillation was induced and sternal chest compression was immediately begun with a pneumatic chest compressor (Thumper) that was modified to provide a continuous signal of piston displacement. Compression force was initially set to produce a mean aortic pressure of 80 mmHg at a standard rate of 100/min and a duty cycle of 60%. Force was left unchanged for the remainder of the experiment. Lungs were ventilated after every fifth chest compression. Data accumulation started after 10 min of CPR because of early time-dependent decreases in mean aortic pressure to 60 mmHg. In addition, epinephrine was continuously infused (10 ug/kg/min, iv) to minimize decreases in aortic pressure as CPR was prolonged. CPP was measured 30 sec after switching to 48 combinations of 6 rates and 8 duty cycles in each animal. At each rate, duty cycle was increased from 10% to 80% in 10% increments. The rate was then switched in a randomized order and stepwise duty cycle increments were repeated. Stability was ascertained by return of CPP to baseline values at a rate of 100/min and 60% duty cycle before switching to the next rate.

Results. In the large, 8 week old piglets, increasing the duty cycle led to increases in mean aortic pressure at each compression rate. Sagittal sinus pressure also increased, but to a lesser extent. As a result, CPP increased (Table 1). At long duty cycles however, CPP began to decline. Thus there was an optimum duty cycle. Inspection of the data reveals that the optimal duty cycle was lower at higher compression rates. At rates of 40, 60, 80, 100, 120 and 150 per min, the corresponding optimal duty cycles for CPP were 60%, 50%, 50%, 45%, 40% and 30%. Cyclic displacement of the sternum remained constant at 20% of the anteroposterior chest diameter until the duty cycle was increased above these optimal duty cycles. Above these optimal duty cycles, recoil of the chest during the relaxation phase of the cycle progressively became incomplete and cyclic displacement then declined. At rates of 40, 60, 80, 100, 120 and 150 per min, the duty cycles at which cyclic displacement began to decline were 80%, 70%, 70%, 60%, 50% and 40%, respectively. The corresponding durations of the relaxation phase were 300, 300, 225, 240, 250 and 240 msec, respectively.

In the smaller, 2 week old piglets, results were qualitatively similar. The optimal duty cycles were approximately 80%, 75%, 70%, 70%, 65% and 45% at rates of 40, 60, 80, 100, 120 and 150 per min, respectively. Cyclic displacement started to fall at duty cycles of 80%, 80%, 70%, 70%, 60% and 50%, respectively. The corresponding durations of the relaxation phase were 300, 200, 225, 180, 200 and 200 msec. These durations were slightly shorter than those in the larger piglets.

Discussion. These data show that duty cycle is a primary determinant of mean CPP in both age groups. Only in the extreme ranges was CPP sensitive to compression rate. Increases in CPP with increasing duty cycle at fixed rates is consistent with an intrathoracic pressure pump as the predominent mechanism for generating blood flow rather than direct cardiac compression in both age groups of piglets. The primary limitation with using long duty cycles was the time required for the chest to recoil which was relatively constant in absolute msec. This minimum duration for relaxation accounted for the shift to lower optimal duty cycles when compression rate was increased. Precise optimal settings may shift when employed for longer than the 30 sec employed at each setting in this study. Nevertheless, these results emphasize the importance for sustaining the duration of chest compression beyond a brief impulse in pediatric as well as adult CPR. (Supported by NIH grant NS20020).

Reference.

1. Halperin et al.: Circulation 73:539-550, 1986

Table 1. Mean CPP in 20 kg piglets

| Rate | Duty Cycle (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| (per min) | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 |
| 40 | 4 | 11 | 17 | 22 | 26 | 26 | 25 | 21 |
| 60 | 16 | 28 | 38 | 36 | 34 | 37 | 37 | 23 |
| 80 | 13 | 22 | 24 | 30 | 33 | 28 | 21 | 7 |
| 100 | 11 | 27 | 37 | 46 | 45 | 34 | 21 | 20 |
| 120 | 9 | 21 | 29 | 32 | 29 | 19 | 8 | 8 |
| 150 | 6 | 31 | 42 | 38 | 24 | 16 | 14 | -- |

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