Although augmentation of central hemodynamics during human sexual intercourse is well established, dynamic changes in human regional cerebral blood flow have not been reported. Noninvasive transcranial Doppler ultrasonography has been well validated and allows direct, continuous measurement of phasic blood velocity in the human middle cerebral artery (a linear index of regional cerebral blood flow). The middle cerebral artery supplies the premotor and primary sensorimotor cortical regions for the arms, upper and lower trunk, and head. Blood velocities in this vessel have been shown to increase significantly with sensory stimuli and physical stresses. Accordingly, we tested the hypothesis that human sexual intercourse increases middle cerebral artery blood velocity. We used noninvasive, transcranial Doppler ultrasonography (95% confidence limits for precision ± 7%) to measure blood velocity in the left middle cerebral artery of 10 male and 10 female, sexually acquainted, healthy adults (age range, 23 to 47 years; mean, 30 years). To eliminate signal artifacts and allow complete freedom of motion, a modified low profile, temporal fossa transducer was secured by minimal unobtrusive forehead strapping. Continuous measurements of phasic blood velocity and heart rate were made in a private bedroom setting during rest (control), preexcitement, excitation, prepenetration, penetration, preorgasm, orgasm, and resolution with the untethered instrumented subject in the supine missionary position. Heart rate and blood velocity responses were similar in both sexes. During orgasm, the maximal heart rate increased significantly ($P < 0.05$): 49 ± 44% in women, 65 ± 32% in men, and 58 ± 38% combined from a combined resting value of 77 ± 11 standard deviations (SD) beats per minute. Importantly, blood velocity in the middle cerebral artery of the 20 subjects remained unchanged ($P > 0.10$) from a resting value of 56 ± 15 cm/s. In conclusion, in both sexes, human middle cerebral artery blood velocity, a linear index of human regional cerebral blood flow, does not increase significantly ($P > 0.10$) during human sexual intercourse. Key Words: Cerebrum, blood flow; Doppler ultrasonography; Sexual intercourse; Coitus; Blood flow velocity, cerebral artery.

**ABBREVIATIONS**

PET, Positron emission tomography; TCD, Transcranial Doppler ultrasonography; SD, Standard deviation; HR, Heart rate; MV, Maximum velocity
the scientific community to investigate human physiologic responses during coitus. Recent (July 2000) Medline and other comprehensive literature searches have revealed only one report of an increase in cerebral blood flow (by PET scanning) of the right prefrontal cortex during male masturbation. Again, no blood flow data exist in the published literature for private, unconstrained human sexual intercourse to orgasm.

Recent development of portable noninvasive TCD has allowed direct and dynamic (6 ms time resolution) measurement of blood velocity in human basal cerebral arteries, including the middle cerebral arteries, which are the major supply conduits to each hemisphere. The middle cerebral arteries supply the premotor and primary sensorimotor cortical regions for the arms, upper and lower trunk, and head. Importantly, if the diameter of the middle cerebral artery and the Doppler angle of insonation are assumed to remain constant under normal experimental and physiologic conditions, changes in middle cerebral blood velocity are linearly proportional to independent standard measurements of regional blood flow. This well-validated, noninvasive method has been extensively applied clinically. It is widely used to test numerous physiologic hypotheses, which relate age, sex, or various physical stimuli to human middle cerebral artery blood velocity and thus dynamic changes in regional cerebral blood flow. Clearly, numerous stimuli affect cardiovascular and pulmonary function during various phases of sexual intercourse. TCD allows the opportunity to measure regional cerebral blood flow changes during sexual intercourse without compromising the integrity and natural progression of the event. The nature of sexual intercourse would inherently incorporate an elevation in sensory stimulation and motor responses. Thus, we may hypothesize that elevations in regional (hemispheric) cerebral blood flow would occur. Furthermore, differences in cerebrovascular responses between the sexes have been reported and may, indeed, occur during sexual activity. Importantly, hemodynamically significant changes in phasic regional cerebral blood flow during sexual intercourse may also have clinical implications in ischemia, hemorrhage, emboli, endothelial function, and general mass transport phenomena. Accordingly, we tested the hypothesis that human sexual intercourse increases middle cerebral artery blood velocity.

METHODS

Subjects

After providing informed consent, 20 healthy, non-smoking subjects (age range, 23 to 47 years; mean, 30 years ± 6 SD) consisting of 10 men and 10 premenopausal, nonmenstruating women volunteered for participation in the study. All couples were sexually acquainted with a minimum of 20 previous sexual encounters. All subjects were instructed as to the experimental procedures and were familiarized with equipment before each experiment. Subjects refrained from alcohol and caffeine 6 hours prior to participation. None of the participants were taking any vasoactive medication.

Measurements

The procedure was designed to be as unobtrusive as possible to ensure that sexual intercourse was as natural to the couples as possible. The TCD method has been described in detail previously. Here, the temporal fossa transducer (+ 1.0 cm3) fits securely in place on one of the partners to insonate the left middle cerebral artery with the highest possible signal-to-noise-ratio. A 2.0 cm wide Velcro headband attached the transducer with a lightweight, narrow, 3 m long connecting cable allowed complete freedom of movement. A 2 MHz TCD flowmeter (Medasonics, Model CDS, Fremont, CA) was used to measure middle cerebral artery blood velocity spectral waveforms at a depth of approximately 45 to 55 cm. Continuous Doppler blood velocity spectral waveforms (6 s and 20 dB dynamic range) were recorded on a two channel portable audiotape recorder (Optimus, Radio Shack, Fort Worth, TX). The instrumented subject was in the supine missionary position to eliminate motion artifacts and minimize metabolic expenditure. In all cases, the female partner was instrumented first and undertook sexual intercourse until orgasm and resolution. The man was then instrumented and monitored throughout the various phases. To identify each specific phase of intercourse, the instrumented subject used a small (±1 cm3) handheld switch, which would send a 0.5 volt audio event marker to the audiotape when clicked. This allowed couples to proceed privately and at a pace comfortable and natural to them. The investigators were not in the vicinity during testing. All participants considered the small transducer and the minimal bedside instrumentation to have little, if any,
influence on their activity. The standard phases of sexual intercourse were modified from the criteria of Masters and Johnson. Continuous measurements were taken during each of the following phases: (1) rest (control); (2) preexcitement; (3) excitation; (4) prepenetration; (5) penetration; (6) preorgasm; (7) orgasm; and (8) resolution. The excitement phase was signaled when the partner entered the room, and the orgasm phase was the immediate onset of orgasm. The resolution phase was noted when the subject relaxed after orgasm. The phases were well described to all subjects with instructions when to use the event maker. From recorded spectral waveforms, a blinded observer used off-line software to calculate HR and the temporal mean of the spatial MV envelope. Reported mean ± SD values were calculated from the last 10 s during each of the eight phases given that were signaled by the subjects.

Statistics

Analysis of covariance was used to determine significance (P < 0.05) of percentage changes from resting control of HR and MV at all eight phases of sexual intercourse. Any significant sex differences for all corresponding phases of sexual intercourse also were determined. In our hands, the 95% confidence levels for percentage changes (precision) in MV are ± 7%. As a measure of biologic variance within one couple, measurements from three repeated tests on the same couple on three different days gave absolute values of HR and MV at each phase within 10% of those from the initial procedure. All values are given as means ± SD.

RESULTS

The total duration of sexual intercourse ranged from 16 min to 55 min (mean, 29 ± 12 min). Figure 1 illustrates typical Doppler spectral blood velocity waveforms during rest (phase 1) and orgasm (phase 7). In general, the waveforms exhibited minimal, if any, artifact. Figure 2 shows the individual and means ± SD of the percentage changes in HR in the female and male subjects during the eight phases. The mean resting HR was 77 ± 11 bpm and increased 58 ± 38% to a maximum of 117 ± 16 bpm at orgasm. HR in men and women at orgasm increased significantly by 66 ± 32% and 49 ± 44%, respectively. Significant changes in HR occurred in men during penetration, preorgasm, and resolution. Significant changes in HR were reached only during preorgasm and orgasm in women. No significant differences were found according to the sex of the subject.

Figure 3 shows the individual and means ± SD of the percentage changes in MV in the 10 female and 10 male subjects. The mean resting MV was 58 ± 16 cm/s. Surprisingly, no significant differences (P > 0.10) in MV of the 20 subjects at any phase compared to rest or between the sexes.

DISCUSSION

The control of human global and regional cerebral blood flow is very complex and involves both large and small cerebral blood vessels. Regional and global cerebral blood flows respond to sensory stimuli and to physical stimuli, such as static and dy-musculomotor activity.
namic exercise, in different manners. Furthermore, as an index of regional blood flow, MV increases with sensory stimuli and exercise. These reports of significant changes in MV and the findings of Tihonen and coworkers lead us to hypothesize that an increase in MV would occur during sexual activity. As expected, mean HR increased approximately 58%. With this HR response and the subjects in the supine position without intensively using large muscle masses, a modest metabolic expense would be expected. Nevertheless, changes in ventilation and any sensory stimuli could affect MV. Surprisingly, in this observational study, MV did not increase during sexual activity in either men or women. To minimize intrusion and maximize the natural course of sex activity, we did not measure ventilation or PCO₂. Thus, we cannot eliminate any attenuation of an exercise or sensory stimuli induced increase in MV by assumed ventilatory hypocapnia. If, indeed, the respiratory rate increased threefold to fourfold, the resultant hypocapnia could decrease MV at a rate of approximately 3 to 4% per mm Hg of PCO₂. Thus, depending on the ventilatory response, hypocapnia could have decreased an elevated MV by 30 to 40% to maintain control levels.

The middle cerebral artery diameter was not measured in the present study and, therefore, a change in diameter of the vessel could potentially affect total flow. Research has revealed that changes in the cerebral artery diameter have occurred while undertaking hand grip exercise. The methodology used in the present study, estimating middle cerebral artery flow from middle cerebral flow velocity, has, however, been strongly supported in the recent research, which revealed no significant change in cerebral vessel diameter with several physiologic stressors, including simulated orthostasis and manipulated end-tidal CO₂ partial pressures.

Under the observed HR increases and assumed ventilatory responses, the influences of any changes in blood pressure and PCO₂ on the diameter of the middle cerebral artery would be minimal and would have a negligible effect on MV. Indeed, the repeated normal and biologic variations of TCD measurements are ± 7% over 5 min.

The previously reported gender differences in resting and stressed MV were not observed during sexual intercourse. Thus, we speculate that any behavioral or psychologic gender differences during sexual intercourse appear not to be related to the cerebral region, which is supplied by the left middle cerebral artery. Owing to reported symmetry in the reproducibility and responses of the left and
right middle cerebral arteries during rest and generalized activities, we arbitrarily chose to investigate only the left vessel.

Importantly, since the group mean of MV remained relatively constant, sexual intercourse appears not to accentuate hemodynamic or mass transport effects in the region of the middle cerebral artery in patients with cerebrovascular disease. Studies with careful control of ventilation in different patient populations would need to be undertaken to address this important issue.

We conclude that regardless of a subject’s sex, sexual intercourse does not significantly increase human regional cerebral blood flow, as indexed by changes in middle cerebral blood velocity. We speculate that ventilatory hypocapnic vasoconstriction or, to a lesser extent, cerebrovascular autoregulation, may attenuate any stimulus-induced increase in cerebral blood flow during sexual intercourse. Clearly, Doppler ultrasonography is a useful method in future investigations in this neglected field of human cardiovascular physiology.

REFERENCES


**Figure 3** Individual female (A) and male (B) percentage changes from rest (%Δ) in the temporal MV of the middle cerebral artery during the eight phases of sexual intercourse. C, Female and male means and standard deviations are shown at the bottom. See legend for Figure 2 for the respective phases. Female subjects are indicated with a broken line and male subjects with a solid line. No significant changes (P < 0.05) were noted in MV during the phases.