HYPOTHERMIA IN CLINICAL MEDICINE

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INDUCTION

METHODS

1. Surface cooling simple and practical.
2. Ice water immersion - rapid and efficient.
3. Circulating blanket - prolonged periods of lowered body temperatures.
4. Ice bags in children (and adults) if other methods unavailable.

DRUGS

1. Anesthesia - to control shivering and extreme vasoconstriction.
   a. Muscle relaxants (curare, succinylcholine, etc.)
2. Heavy sedation - rapid cooling for non-operative applications.
   a. Parenteral barbiturates and scopolamine.
3. Phenothiazine derivates - depress shivering and vasomotor over-activity.
   a. 25 mg. I.V. until desired effect is achieved.
4. Ganglionic blockers to overcome vasoconstriction.

CONTROLS

1. Temperature: thermometer with thermistor probe.
2. Blood pressure: intra-arterial recording when auscultation not feasible.
3. Heart: continuous ECG monitoring.
4. Respiration: IPPB device of the "assistor-controller" type.
   a. Depression from sedation or anesthesia.
   b. Mandatory with use of muscle relaxants.

PRECAUTIONS

1. Avoid frostbite and protect pressure points.
   a. Temperature of cooling medium should not go below freezing.
2. Avoid excessive "temperature drift".
   a. Stop cooling process 2^{o}-4^{o} above desired temperature.
3. Avoid hypotension.
   a. Precedes serious cardiac arrhythmia.
4. Avoid respiratory depression.
   a. Respiratory rate decreases with temperature fall.
   b. Depth of respiration should remain normal or increase.
5. Avoid cardiac irregularities.
6. Avoid panic.

RE-WARMING

1. Permit the patient to re-warm himself.
    a. Rewarm rapidly if trouble develops.
2. Observe circulation closely during re-warming period.
    a. Blood pressure should be estimated frequently.
3. Avoid temperature "overshoot".
    a. Compensatory hyperthermia usually occurs on rewarming.

CENTRAL NERVOUS SYSTEM

Recommended Temperatures 82-86°F (28-30°C)

OPERATIVE

1. Vascular occlusion for 12-14 minutes.
    a. Useful in vascular lesions of the brain.
2. Cerebral vessel ligation with minimal post-ligation sequela.
3. "Slack" brain for difficult exposures or in increased intra-cranial pressure.
    a. Useful in surgery of pituitary and hypothalamus and in large space occupying lesions.
4. Reduces post-operative brain swelling and edema.

TRAUMA

1. Prevents or decreases cerebral edema.
2. Prevents or reduces effects of ischemia of compressed brain tissue in intra-cerebral hematomata.
3. Combats hyperpyrexia associated with head injuries.

POST-ANOXIA

1. Reduces degree of cerebral edema following cardiac arrest or other anoxic insult.
2. Prevents hyperpyrexia following anoxic episodes.
3. May reverse moderate neurological damage following anoxia.

INTRA-CARDIAC SURGERY

HYPOTHERMIA ------ TOTAL CIRCULATORY OCCLUSION

RATIONALE

Extended occlusion time	4 minutes	98.6°F (37.0°C)
	10 minutes	86.0°F (30.0°C)
	15 minutes	79.0°F (26.0°C)

INDICATIONS

Interatrial Septal Defect-Septum Secundum	79.0°F (26.0°C)
Pure Pulmonary Valvular Stenosis	86.0°F (30.0°C)

COMPLICATIONS

Ventricular Fibrillation - controlled by adrenalin and electrical defibrillation.

HYPOTHERMIA ----- PUMP OXYGENATOR TOTAL BY PASS

RATIONALE

Reduce blood flow - 88°F 1/2 of normal.
Safety factor in event of pump failure.
Pump time up to 1 hr. 45 min.
Damage to blood cellular elements decreased.
Biochemial derangement - metabolic acidosis decreased.

INDICATIONS

All intracardiac lesions, congenital and acquired.

COMPLICATIONS

Possibility of arrhythmias increase while cool.

GENERAL

	Reduces metabolic cost.
	Increases cardiac efficiency.
	Slows heart rate.
RECOMMENDED TEMPERATURE	Conserves renal function.
92-86°F (34-30°C)	Protects central nervous system.
	Mitigates stress.

Above Rationale applies to Indications listed below in addition to alterations specific for each condition.

ACUTE VASCULAR COLLAPSE	Decreases bacterial toxin formation & action
Septic Shock	Improves myocardial contractility.
Myocarditis	Vascular pressor effect.
Anuria	Enhances urinary excretion.
THYROTOXICOSIS	Decreases thyroxin formation and effect.
GI BLEEDING	Inhibits gastric secretion digestive action.
	Inhibits motility.
LUNG DISEASE	Reduces bacterial toxin effect.
Fulminating inflammatory	Reduces work of breathing.
Acute insufficiency	Does not inhibit host immunological activity.

ECLAMPSIA	Decreases cerebral edema Reduces anesthesia requirement. Enhances Na excretion.
CARDIAC ARREST	Decreases cerebral edema.
SURGERY "Poor risk" patient Hemorrhage Burns	Vascular pressor effect Prevents added stres of surgery. Reduces anesthesia requirement. Analgesic effects (reducing narcotic need). Decreases peripheral fluid loss.

MANAGEMENT

1. Slow alterations in temperature.
2. Maintenance of fluid and electrolyte balance.
3. Whole blood or plasma transfusions as required.
4. Tracheobronchial toilet-tracheostomy when necessary.
5. Frequent turning of patient.
6. Adequate monitoring of vital signs.
7. Rewarm slowly.

PITFALLS

1. Persistent shivering - control with phenothiazine.
2. Excessive temperature drift - keep above 86^{0}F (30^{o}C)
3. Temperature "overshoot" - recool if persists over 24 hours.
4. Inadequate electrolyte balance - low sodium and chloride.
5. Failure to follow fundamental principles - Hypothermia is an adjunct - not the therapy.

PHYSIOLOGY

ABBREVIATIONS AND SYMBOLS

A-V O_2	Arterio-venous oxygen difference	EC Space	Extracerebral space
Vasc.Res.	Vascular resistance	C.O.	Cardiac output
MRO_2	Metabolic requirement for oxygen	TPR	Total Peripheral resistance
Csp.P.	Cerebrospinal pressure	GFR	Glomerular filtration rate
MV	Minute ventilation	D	Decrease
		≠	Increase

EXPLANATORY NOTES

Values are quantitated as per cent of normothermia. N - normal limits (of normothermia); ≠ increased - D reduced. Asterisk (*) - human data. The date are in their customary values; e.g., electrolytes in mEq/L and A-VO_2 diff. in volumes per cent. The figures are derived from surface cooling (tub immersion or blanket) and rewarming. They are of short term (not over two hours) stabilized hypothermia. The anesthesia in humans consisted of pentothal, cyclopropane or ether and curare. Animal data were obtained from dogs anesthetized initially with either pentobarbital or chloralose. Re-warm to 37°C (98.6°F).

T°C	33	30	25	R
T°F	92	86	77	R

CARDIOVASCULAR

Total Bld. Vol.	-	74	70	N
Plasma Volume	-	N	87	N
Hematocrit	N	N	134	N

CIRCULATION

Arterial B.P.	120	N	75	N
Venous P.	N	82	115	140
T.P.R.	110	130	170	120
A-VO_2 Diff.	N	N	N	122
C.O.	70	50	20	85
Pulse P.	119	N	53	120
Reflexes	N	D	DD	N

HEART

Bld. Flow	80	60	40	-
Vasc.Res.	-	D	DD	-
MRO_2	83	67	50	-
Efficiency	N≠	135	95	-
Excitability	N	150	230	N
Arrhythmia*	16	28	88	10
Rate*	83	67	50	75

T^oC	33	30	25	R
T^oF	92	86	77	R
RESPIRATORY				
Rate	-	35	25	N
MV	-	32	13	120
Efficiency	N	30	10	N
O_2 Cons.	65	50	35	120
Diffusion	-	n	n	n
pH	N	D	DD	N
O_2 content	N	N	D	N
CO_2 content	N	108	126	94
CO_2 stimulus	N	D	0	N
CNS				
Bld. Flow	80	65	30	-
	-	73	-	-
A-VO_2 Diff.	N	N	N	-
	-	N	-	-
Vasc. Res.	110	120	150	-
	-	125	-	-
MRO_2	80	65	30	-
	-	55	-	-
Csp. P.	N	70	50	-
EC Space	-	-	132	-
Sensorium	N	D	DD	N
LIVER				
Splanchnic B.F.	84	62	37	-
MRO_2	-	-	53	-
BSP	-	-	73	-
Bile Flow	-	33	18	117
Liver Q_{O_2}	83	57	37	-
Volume	N	↗	↗↗	-
ADRENAL				
Corticoids	-	58	24	89
ACTH	-	-	20	400
Epinephrine	-	-	7	N
Norep.	-	-	2	50

T^oC	33	30	25	R
T^oF	92	86	77	R

RENAL

GFR	58	45	30	70
	72	67	-	75
Bld.Flow	70	45	29	70
	70	60	-	75
Plasma Fl.	67	41	27	65
	67	59	-	75
MRO_2	50	31	-	N
Urine Vol.	N	170	350	N
	143	128	-	N

BLOOD CHEMISTRY

Na	N	N	N	N
Cl	N	N	N	N
K	79	74	78	76
Mg	N	N	N	N
Ca	N	N	N	N
Glucose	N	N	122	122
S-GOT	N	N	N	N
NH_3	-	N	83	73

URINE CHEMISTRY

Na	125	124	140	41
Cl	N	107	128	36
K	72	32	20	14
NH_3	62	16	9	51

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References

Collins, W.J. and Granatelli, A. Controlled Hypothermia During Anesthesia in Human Adults. Angiology 6:118-128, 1955

Blair, E., Zimmer, R. and Martin, L. Hemodynamic Effects of Total Circulatory Occlusion During Hypothermia. Surg.,Gyn., and Obst. 108:13-18, 1959

Blair, E., Montgomery, A.V. and Swan, H. Post-Hypothermic Circulatory Failure I. Physiologic Observations on the Circulation. Circulation 13:909-915,1956

Lofstrom, B. Changes in Blood Volume in Induced Hypothermia. Acta Anesthesiol. Scandinav. 1:1-13, 1957

Rosomoff, H. The Effects of Hypothermia on the Physiology of the Nervous System. Surgery, 40:328-336, 1956

Bober, S., et al. Volume of Circulatory Blood in Experimental Hypothermia in the Dog. Pol. Tyg. lek, 12:346-348, 1957

Hallett, E.B. Effect of Decreased Body Temperature on Liver Function and Splanchnic Blood Flow in Dogs. Surg. Forum. 5:362-365, 1954

Sabiston, D.C., Jr., Theilen, E.O. and Gregg, D.E. The Relationship of Coronary Blood Flow and Cardiac Output and Other Parameters in Hypothermia. Surgery 38:498-505, 1955

Rosomoff, H.L. and Gilbert, R. Brain Volume and Cerebrospinal Fluid Pressure During Hypothermia. Am.J. Physiol. 183: 19-22, 1955

Moyer, J.H. Hypothermia I. Effect on Renal Hemodynamics and on Excretion of Water and Electrolytes in Dog and Man. Am.Surg. 145:26-40, 1957

Reissman, K.B. and VanCitters, R.L. Oxygen Consumption and Mechanical Efficiency of the Hypothermic Heart. J.Appl.Physiol. 9:427-430, 1956.

Fisher, B., et al. Some Physiologic Effects of Short and Long Term Hypothermia upon the Liver. Surgery 40:862-873, 1956.

Otis,A.B. and Jude, J. Effect of Body Temperature on Pulmonary Gas Exchange. Am. J. Physiol. 188:355-359, 1957.

Segar, W.E., Riley, P.A., Jr., and Barila, T.G. Urinary Composition During Hypothermia. Am.J.Physiol. 185:528-532, 1956

Blair, E., et al. A Study ofCardiovascular Changes During Cooling and Rewarming in Human Subjects UndergoingTotal Circulatory Occlusion. J. Thor. Surg. 33:707-718, 1957.

Blair, E., Swan, H., and Virtue, R. Clinical Hypothermia: A Study of the Icewater Surface Immersion and Short-Wave Diathermy Technics. Am.Surg.9:889-895, 1958.

Blair, E., and Fellows, J. Pulmonary Ventilation During Hypothermia and on Rewarming. Accepted, J. Thor. Surg.

Buuker, J.P. and Goldstein, R. Coagulation During Hypothermia in Man. Proc. Soc-Expt'l Biol. and Med. 97:199-202, 1958.

Hicks, C.E., Melord, M.C. and Blount, S.G.Jr. Electrocardiographic Changes During Hypothermia. Circulation 13:21-28, 1956.

Mach, Z. et al. Iodine Metabolism in Hypothermia. Pol.Tyg.lek. 12:1571-1575, 1957.

Fedor, E.J., Fisher, B. and Fisher, E.B. Observations Concerning Bacterial Defense Mechanisms During Hypothermia. Surgery 43:807-814, 1958.

Bruck, A., Lohr, B. and Uhmer, W. Animal Experiments on the Regulation of the Respiration in Hypothermia Pharmacologically Enhanced Down to 20°C Body Temperature. Zeitschr. ges. c/p/l. Med. 127:597-604, 1956.

Stone, H.H., Donnelly, C. and Frobese, A.S. The Effect of Lowered Body Temperature on the Cerebral Hemodynamics and Metabolism of Man. Surg.,Gyn., & Obst. 103:312-318, 1956.

The physiology of Induced Hypothermia. N B C Dripps, R-D., Ed. 1956

Hypothermia, Annals N.Y. Acad. Sc., Vol. 80, 1959.