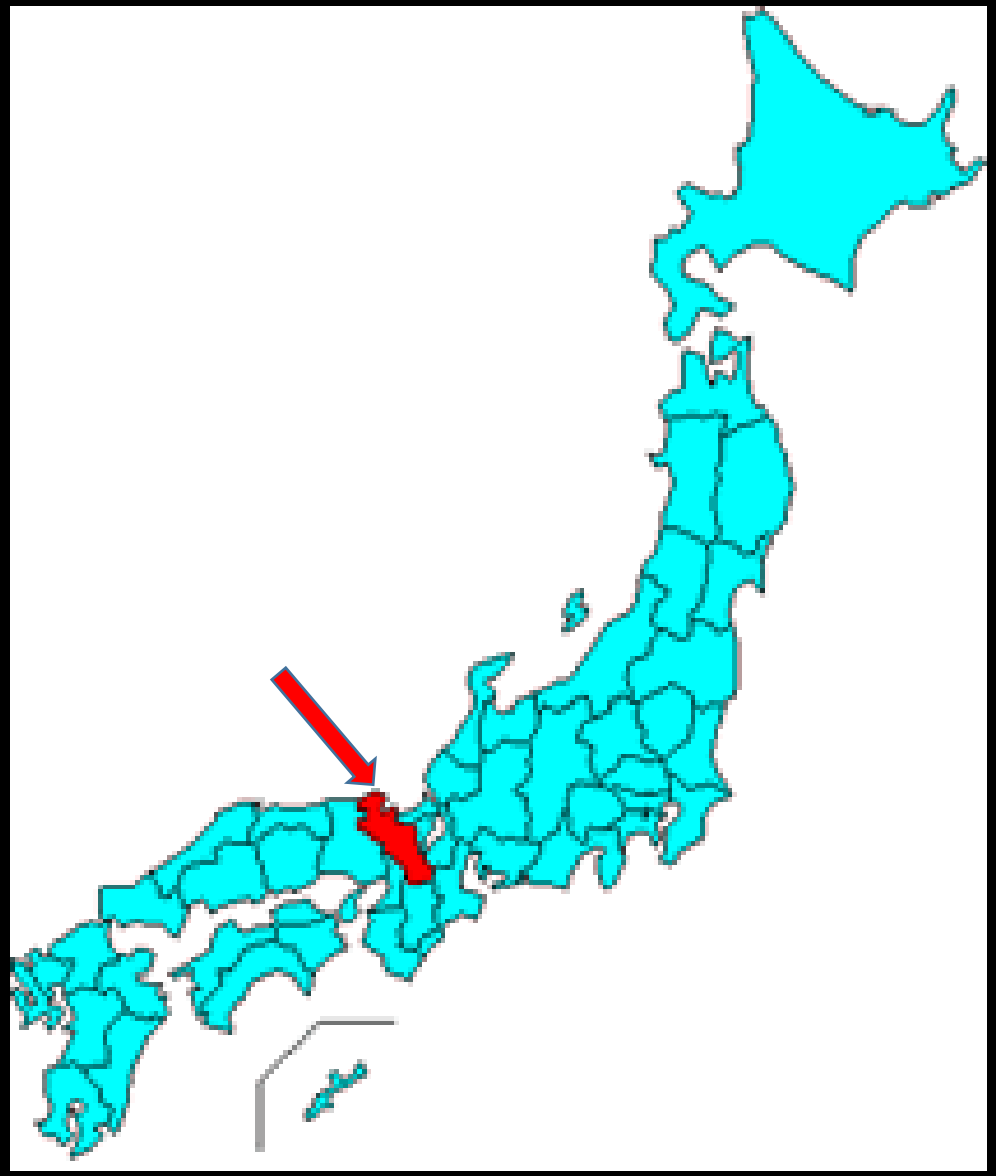
# Cardiovascular abnormality in heat stroke

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Kyoto Japan

Kyoto Prefecture





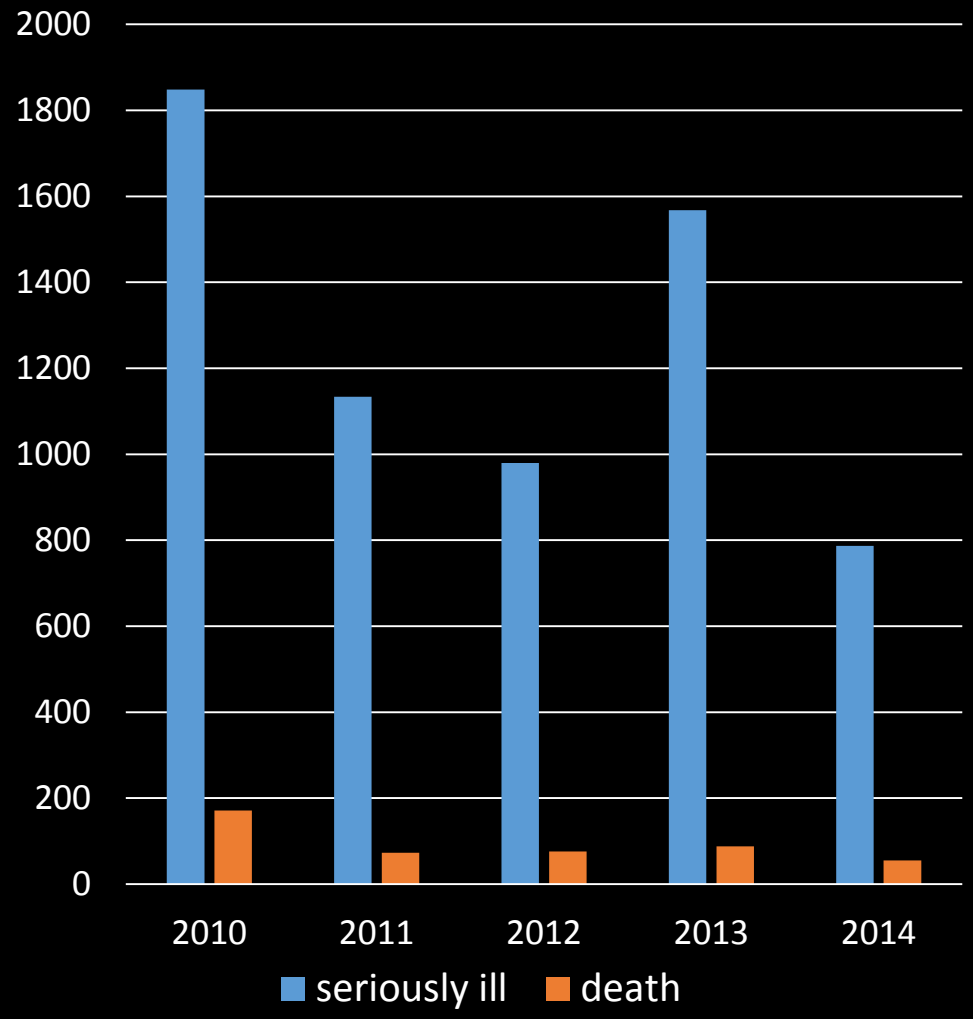

Takeda General Hospital

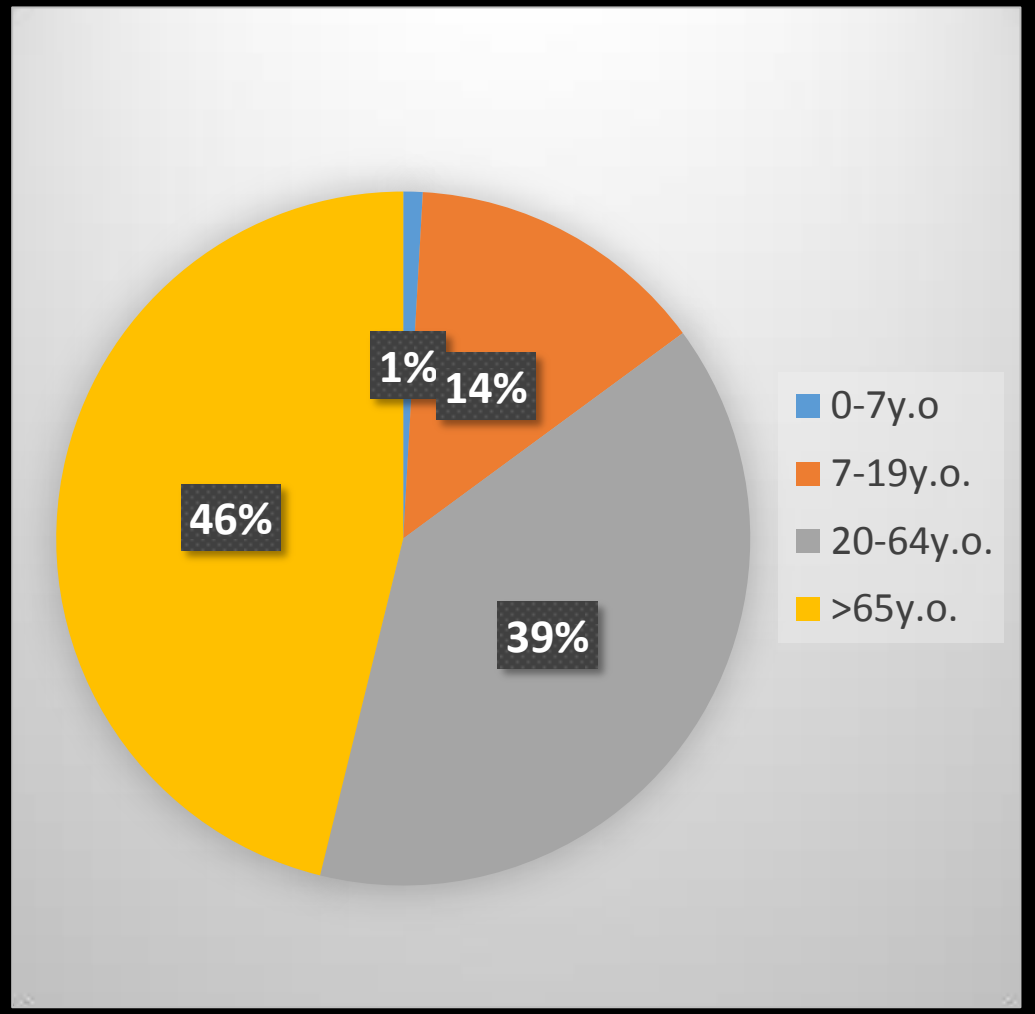

医療法人
医仁会武田総合病院

# Department of Cardiology
# Practical performance

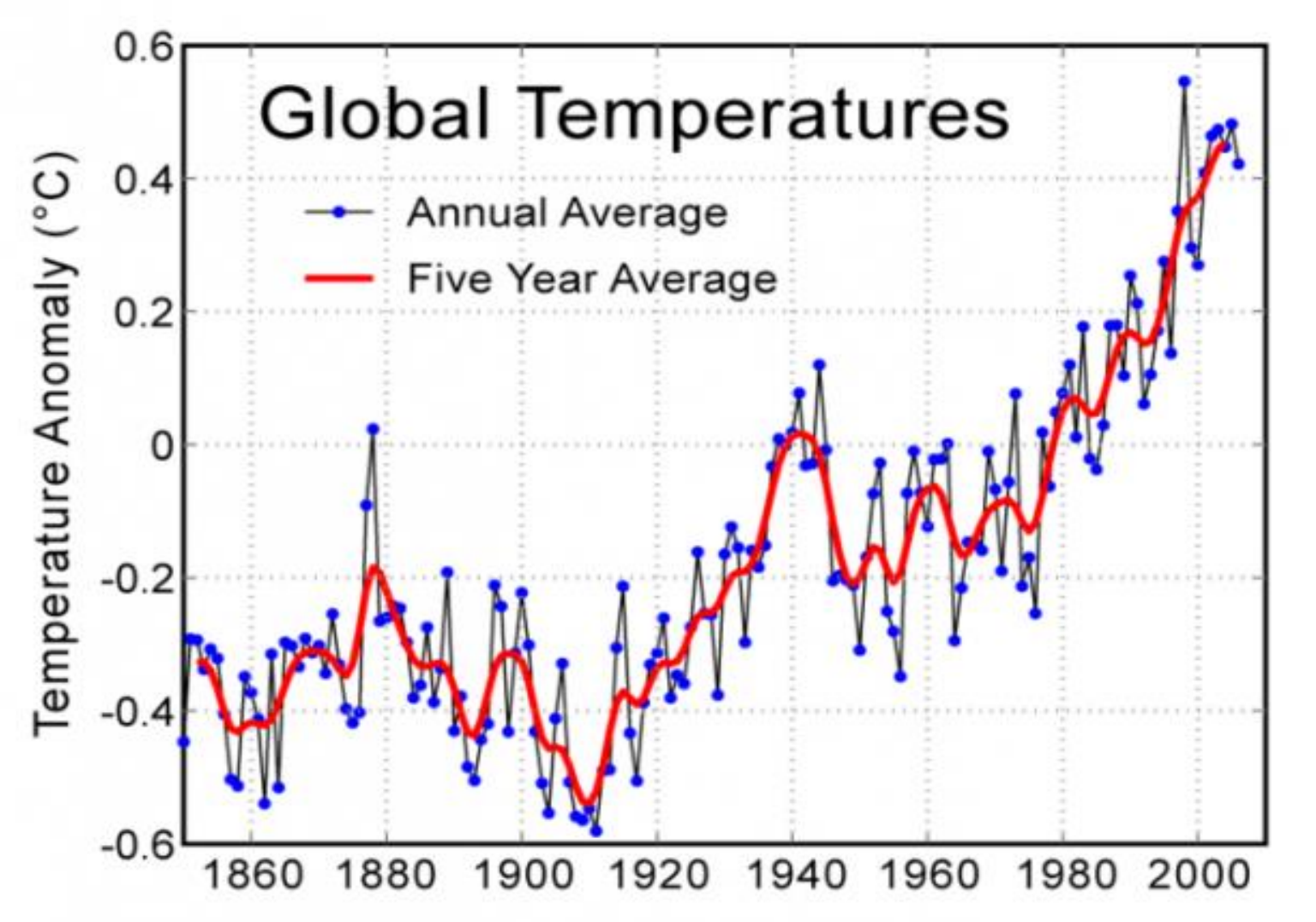
| Year | 2012 | 2013 |
|---|---|---|
| Outpatient (daily) | 23,713 (79.0) | 22,432 (75.8) |
| In patient | 13,391 | 12,306 |
| Cardiac catheterization(PCI) | 982 (291) | 887 (252) |
| Percutaneous peripheral intervention | 89 | 67 |
| Catheter ablation | 94 | 93 |
| ICD/CRT implantation | 54 | 44 |
| Coronary CT | 550 | 446 |
| Ultrasonic cardiography | 7536 | 7551 |
| Treadmill test | 639 | 491 |
| Holter ECG | 388 | 412 |
| | | |

# Heat illness: Epidemiology



# Global warming



# Heat stroke

<Definition>

Severe illness  characterized by a core temperature >40℃

and central nervous system abnormalities such as delirium,

convulsions, or coma resulting from exposure to environmental

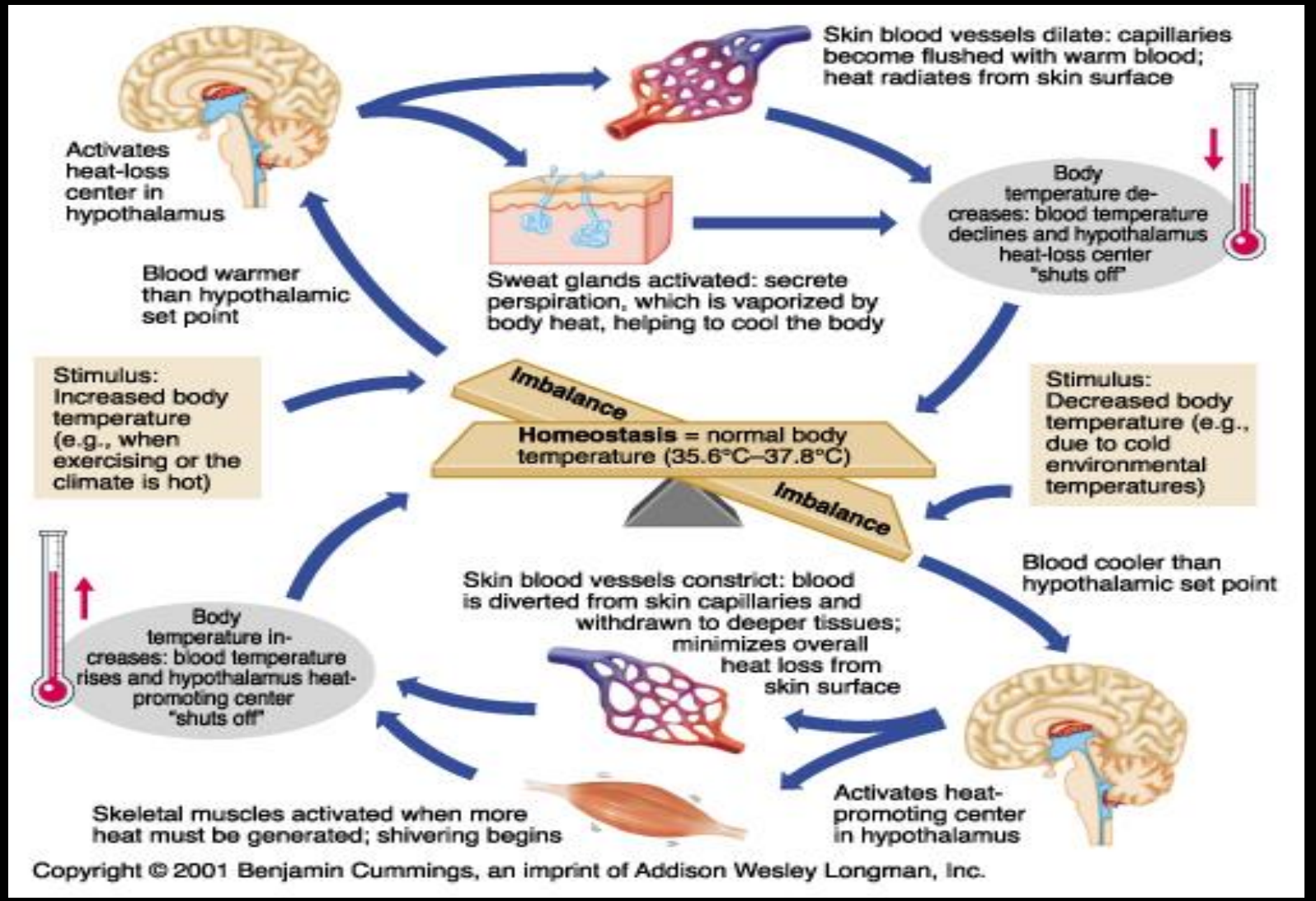
heat or strenuous physical exercise

<Classification>

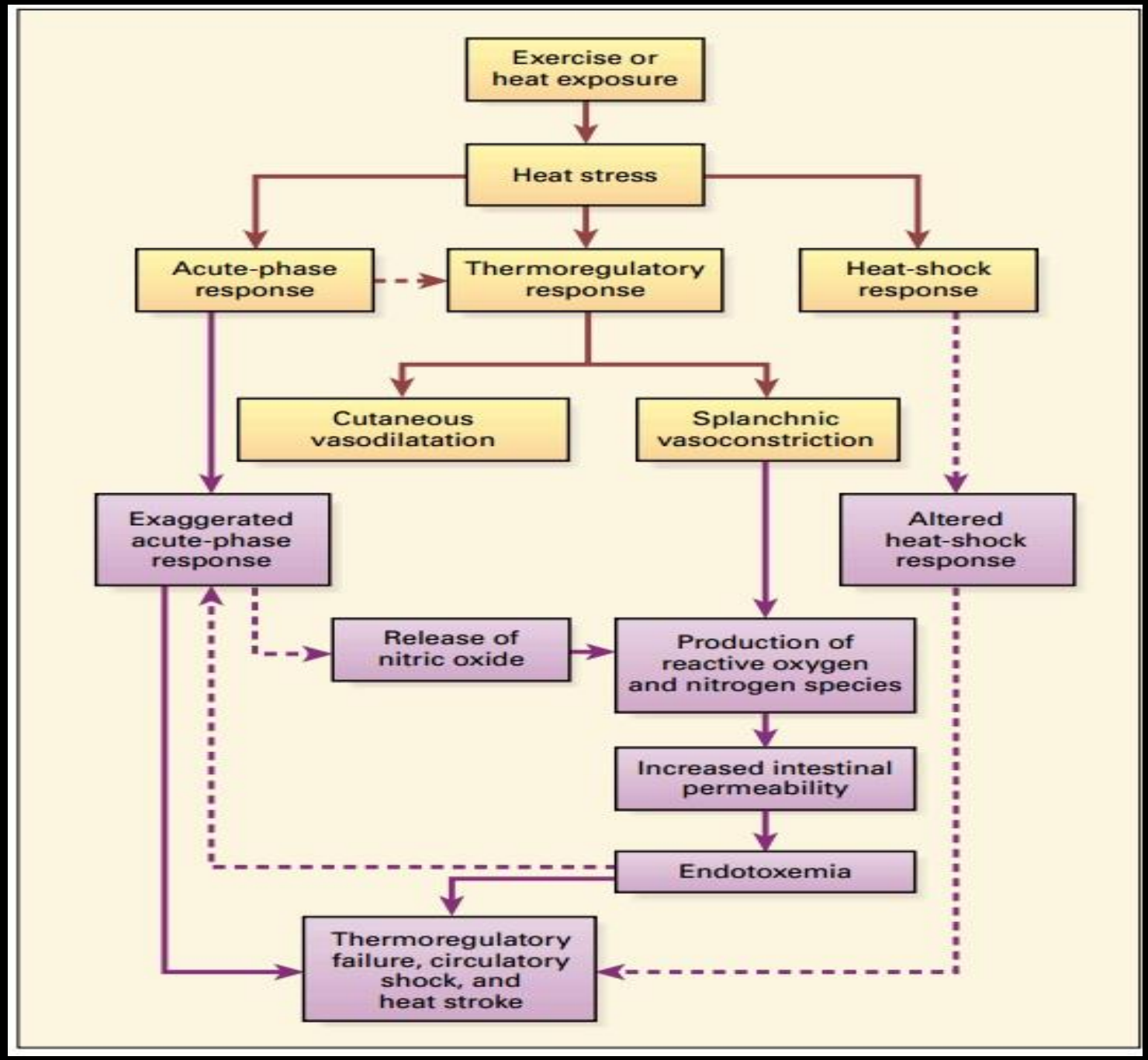
Classic: primary occurs in compromised individuals during annual heat waves

Exertional: in young fit individuals performing strenuous physical exercise

# Thermoregulation

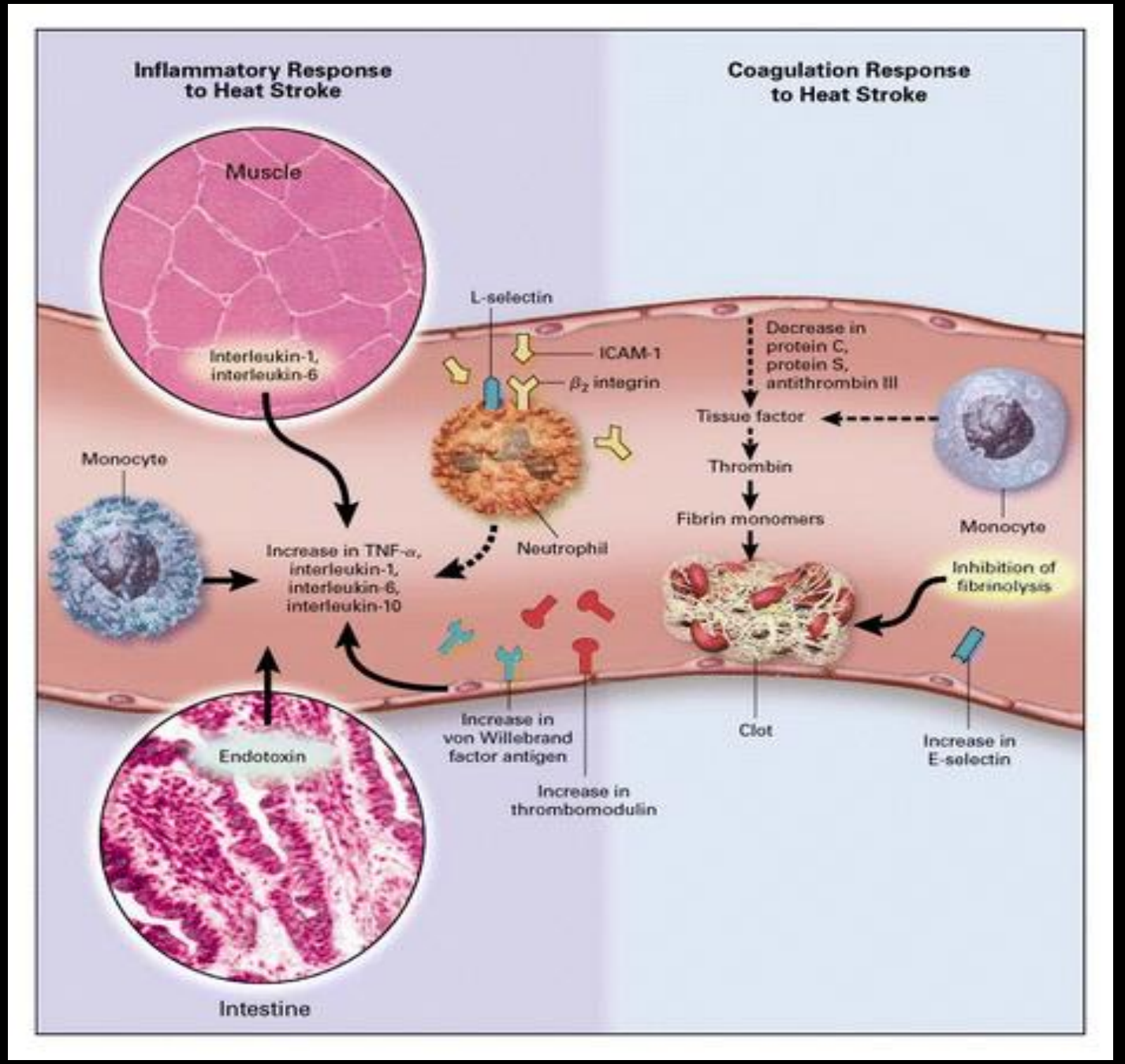


# Progression of heat stress to heat stroke




Bouchama et al, N Eng J Med 346: 2002

# Mediators related to progression to MOF




Bouchama et al, N Eng J Med 346: 2002

# ECG changes in patients with heat stroke

**Table 2—*ECG Changes in Patients With Heat Stroke***

| Parameters | Heat Stroke Patients (N = 46) No. (%) | Probability p Value |
|---|---|---|
| Sinus tachycardia* | 20 (43) | 0.05 |
| Atrial fibrillation | 4 (8.6) | 0.4 |
| Supraventricular tachycardia | 2 (4.3) | 0.5 |
| Bradycardia | 2 (4.3) | 0.5 |
| Increased P-R interval | 2 (4.3) | 0.7 |
| Increased Q-T interval | 28 (61) | 0.007 |
| Conduction defect | | |
| Right bundle branch block | 4 (8.6) | |
| Intraventricular conduction defect | 6 (13) | 0.046 |
| Left bundle branch block | — | — |
| "U" wave | 6 (13) | 0.3 |
| Nonspecific | 12 (26) | 0.036 |
| Diffuse ST-T changes | | |
| Myocardial ischemia | 10 (21) | 0.02 |
| Acute myocardial infarction | 4 (8.6) | 0.2 |
| Old myocardial infarction | 2 (4.3) | 0.5 |

*$\chi^2$ test; Fisher's Exact Test.

Akhtar et al, CHEST 104:1993

# Hemodynamic Data in heat stroke

**Table 2—*Hemodynamic Data for Ten Patients With Heat Stroke****

| Patient | MAP (85-95 mm Hg)† | RAP (2-6 mm Hg)† | CO (3-7 ml/min/m²)† | CI (2.5-4.0 ml/min/m²)† | PCWP (5-12 mm Hg)† Before | PCWP (5-12 mm Hg)† After | MPA (9-18 mm Hg)† | SVR (1,100-1,500 dyne·s·cm⁻⁵)† | PVR (120-250 dyne·s·cm⁻⁵)† |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 60 | 11 | 4.9 | 3 | 14 | 16 | 22 | 800 | 131 |
| 2 | 70 | 8 | 11.4 | 7 | 11 | 15 | 23 | 435 | 84 |
| 3 | 80 | 3 | 9.0 | 4.4 | 13 | 16 | 23 | 708 | 89 |
| 4 | 40 | 5 | 4.6 | 3 | 11 | 15 | 17 | 609 | 104 |
| 5 | 73 | 6 | 4.7 | 2.8 | 8 | 14 | 17 | 1,140 | 153 |
| 6 | 60 | 4 | 15.0 | 8.9 | 6 | 12 | 14 | 299 | 43 |
| 7 | 43 | 6 | 10.4 | 5.4 | 7 | 16 | 13 | 285 | 46 |
| 8 | 53 | 8 | 3.1 | 1.5 | 11 | 13 | 15 | 1,161 | 103 |
| 9 | 90 | 1 | 10.6 | 5.3 | 4 | 9 | 8 | 770 | 30 |
| 10 | 80 | 11 | 8.2 | 3.0 | 13 | 15 | 21 | 634 | 78 |
| Mean | 65 | 6 | 8.2 | 4.4 | 10 | 14 | 17 | 684 | 86 |

*CO = cardiac output; HR = heart rate; MAP = mean arterial pressure; MPA = mean pulmonary artery pressure; PCWP = pulmonary capillary wedge pressure; PVR = pulmonary vascular resistance; RAP = right atrial pressure.

†Values in parentheses indicate normal range.

# Case 1 ( TTC )

87 y.o.  Japanese man

C.C.: consciousness disturbance, generalized convulsion

P.I.: He had a 30-year history of epilepsy and hypertension treated by a neurologist until  17 months previously. He was barely able to walk indoors, had not been eating properly recently. On a hot summer morning of admission, his son found him immobile in the bathroom. His son called an ambulance because the patient gradually became unresponsive and had a convulsion.

# Physical Examination

Consciousness  GCS 6PT, pulse 160-200bpm,

B.P. 110/43mmHg,

B.T. 41.2℃, SpO2 96%( O2 9L mask inhalation)

Skin & tongue: dry

Chest: unremarkable

Abdomen: unremarkable except operation scar

No peripheral edema

# Laboratory data

1.CBC: WBC 16,500,RBC 432x104,Hb 15.5,Htc 42.5,Plat 17.7x104

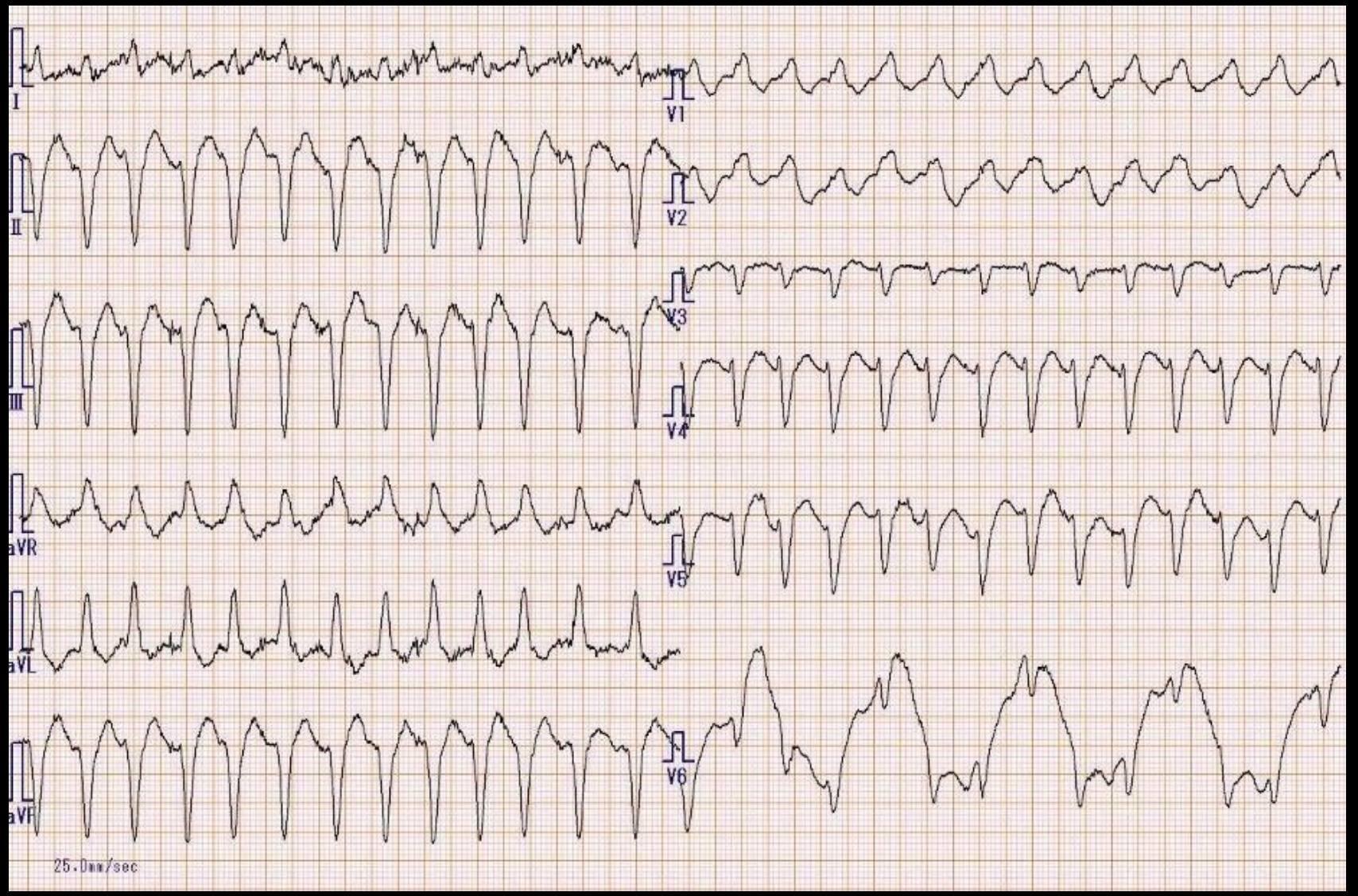
2.Serum Chemistry: T.prot 7.1g/dl, Alb 3.9 g/dl, GOT 82U/L, GPT 38 U/L, LDH 444U/L, Al-P 171U/L, γ-GTP 109U/L, CPK 134U/L, BUN 38mg/dl, Cr 1.88mg/dl, UA 12.4mg/dl, Na 126mEq/L, K 4.2mEq/L, Ca 8.9mg/dl, BS 356 mg/dl, PT(INR) 1.15, APTT 28.0sec, fibrinogen 352mg/dl, CRP 1.37mg/dl

3.Arterial blood gas: pH 7.427, Po2 94.4 mmHg, Pco2 21.7 mmHg, BE -7.8mM/L, Sat O2 96%,AG 21.3mM/L

4.ECG:wide QRS tachycardia, superior axis, atypical CRBBB pattern

5.Chest X-ray: cardiomegaly without pulmonary edema

# ECG on admission

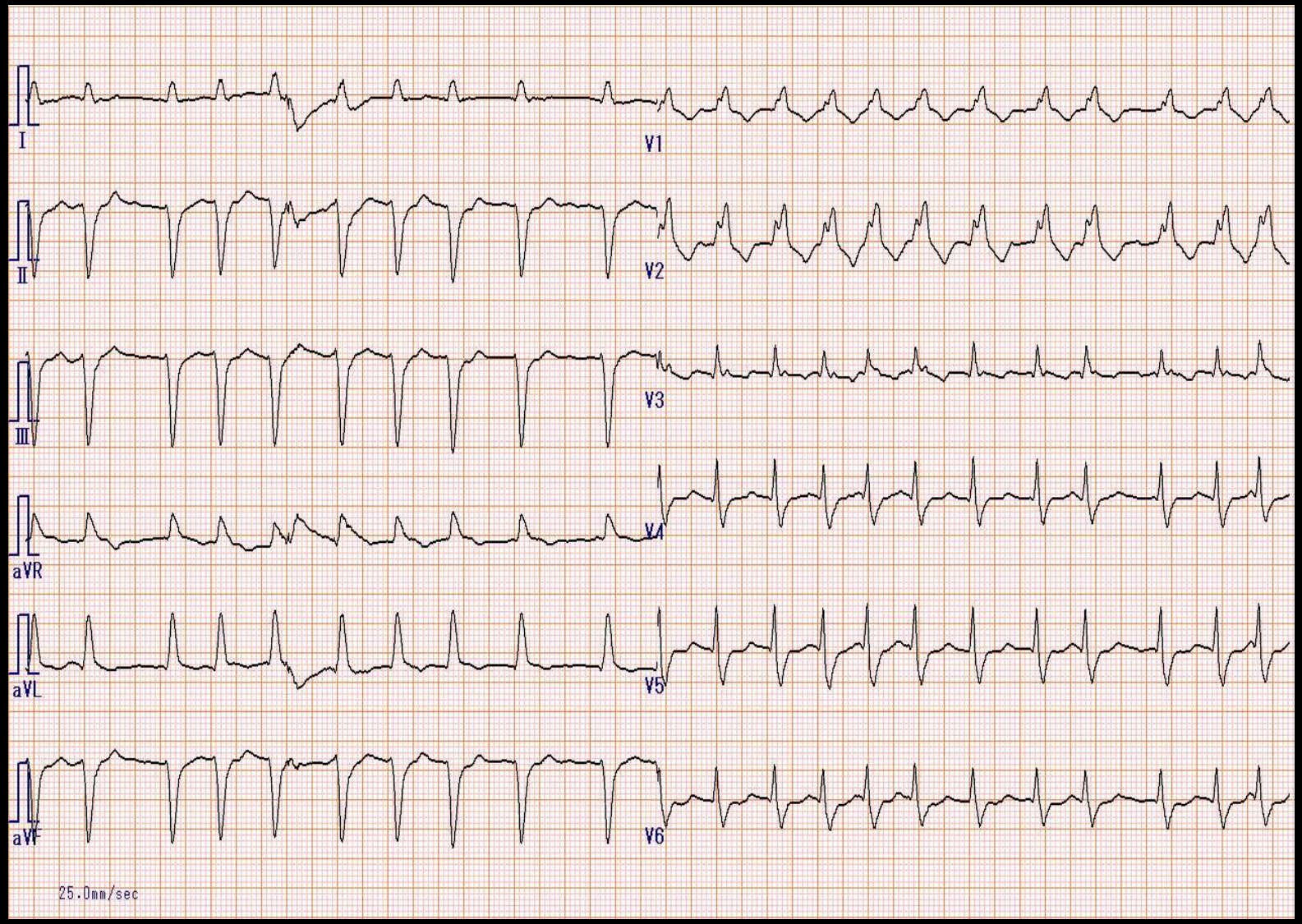


# Initial Management

- Vigorous cooling:

  2L cold normal saline infusion, surface cooling with ice pack
- Intravenous Lidocaine  50mg & Magnesium sulfate 2.46g
- Intubation, Sedation with intravenous propofol

# ECG after lidocaine and Mg



# Management in ICU

- Continue evaporative cooling techniques
- Body temperature 37.5℃　4hours later
- Fell into shock state after conversion to af

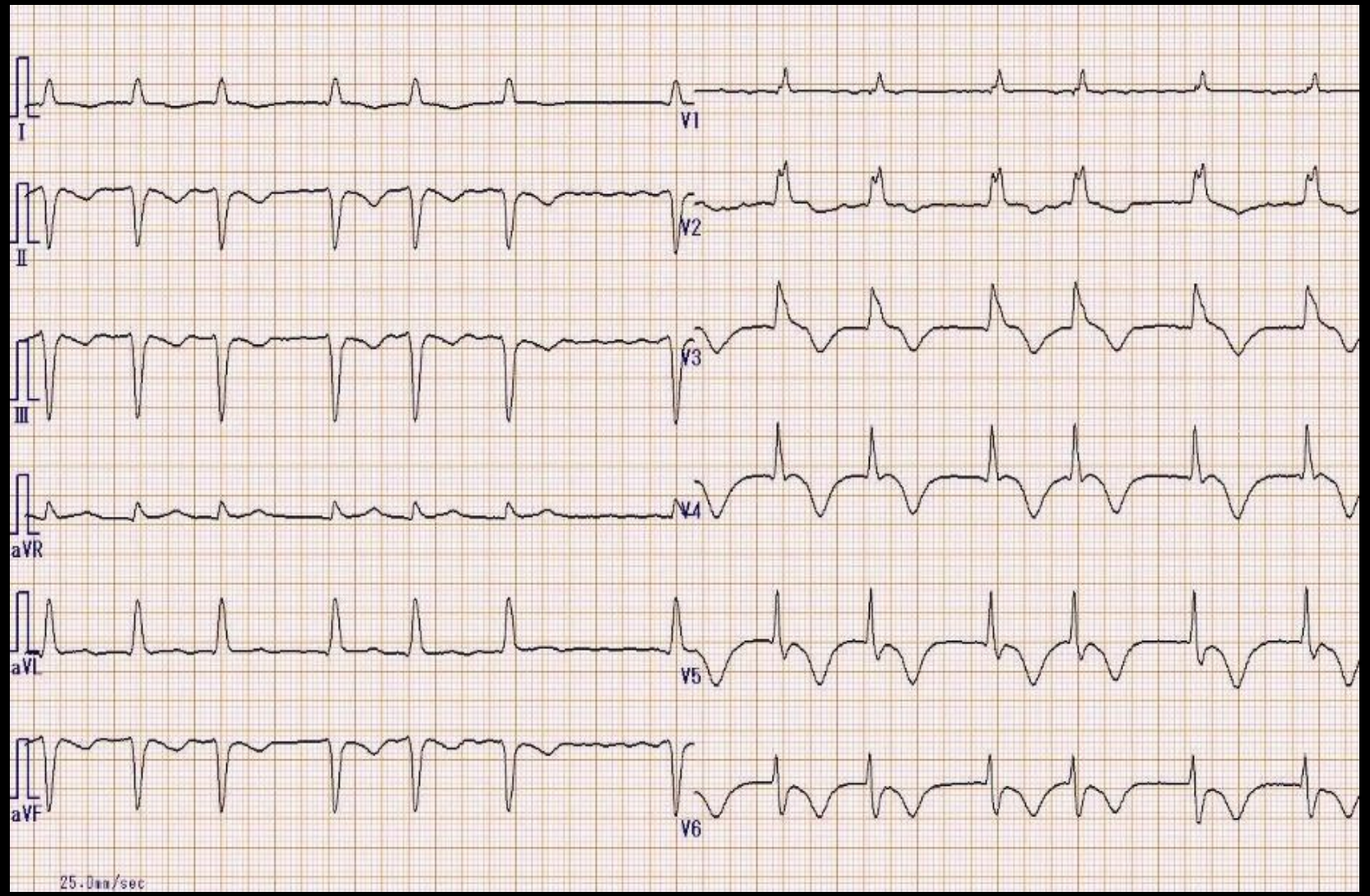
➡drip infusion of NAd(0.3μg/kg/min)  keeping BP >90mmHg

- Drip infusion of Heparin(500U/h) to prevent thrombus formation

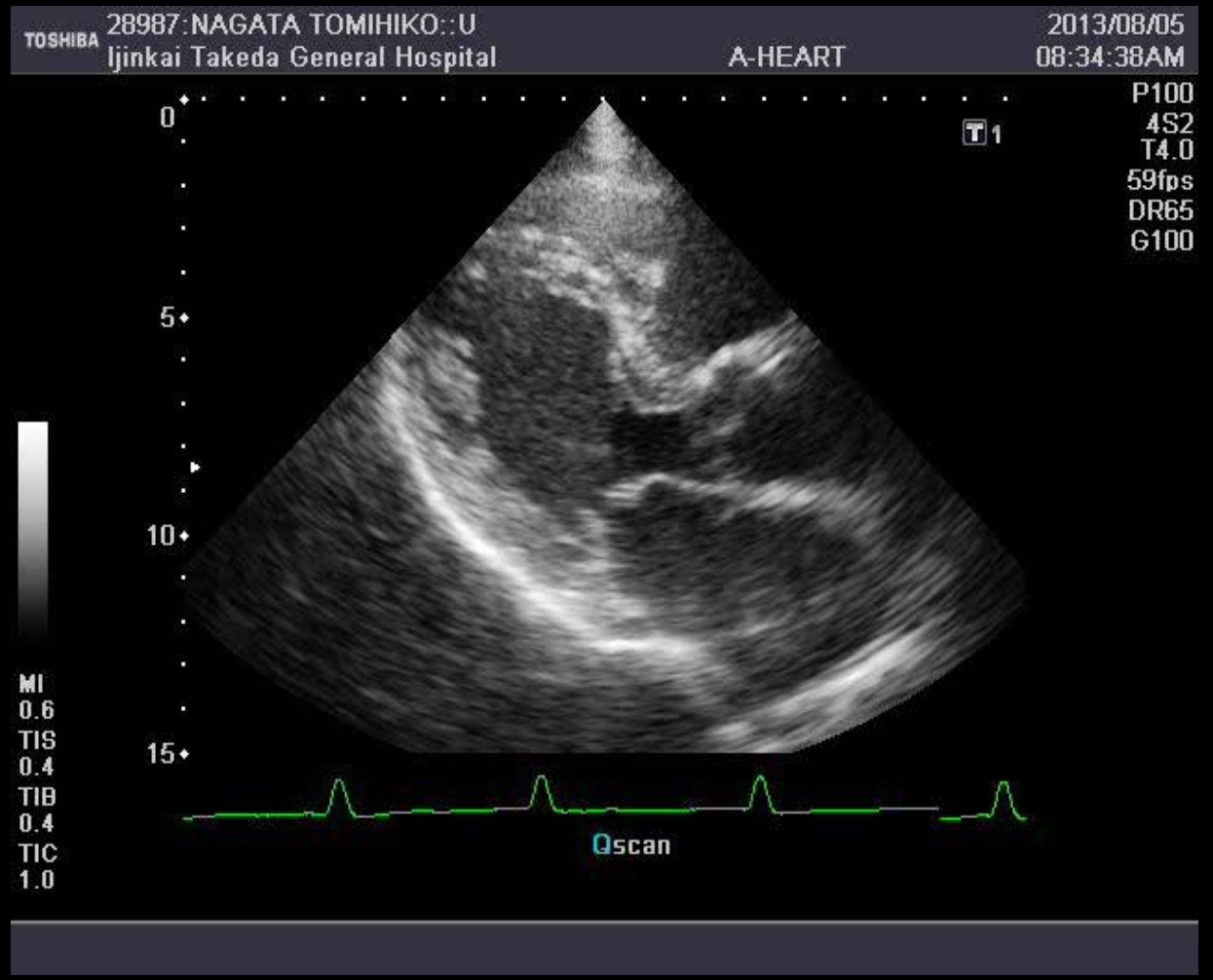
# Serial Laboratory Data

| | DAY1 | DAY2 | DAY3 | DAY8 | DAY14 |
|---|---|---|---|---|---|
| WBC | 16500 | 21400 | 17300 | 12400 | 8700 |
| Plat(x104) | 42.5 | 4.4 | 5.8 | 20.7 | 24.3 |
| INR | 1.15 | | 1.32 | | 1.03 |
| APTT(sec) | 28 | | 46.8 | | 27.6 |
| GOT(U/L) | 82 | 7521 | 2626 | 349 | 223 |
| GPT(U/L) | 38 | 2636 | 1926 | 487 | 389 |
| LDH(U/L) | 444 | 5321 | 953 | 501 | 404 |
| CPK(U/L) | 134 | 4154 | 3866 | 1378 | 182 |
| Cr(mg/dl) | 1.88 | 1.63 | 1.14 | 0.79 | 0.58 |
| UA(mg/dl) | 12.4 | 11.7 | 8.6 | 4.4 | 3.3 |
| CRP(mg/dl) | 1.37 | 3.61 | 2.66 | 3.38 | 0.83 |

# ECG on the next day

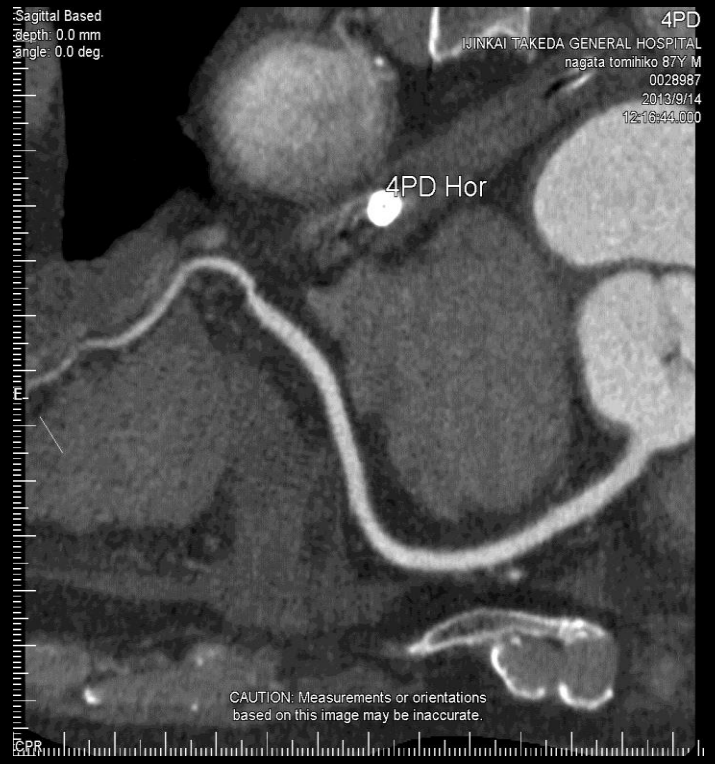


# UCG day2


TOSHIBA
28987:NAGATA TOMIHIKO::U
Ijinkai Takeda General Hospital
A-HEART
2013/08/05
08:34:38AM
P100
4S2
T4.0
59fps
DR65
G100
0
5
10
15
MI
0.6
TIS
0.4
TIB
0.4
TIC
1.0
Qscan

# Coronary CT

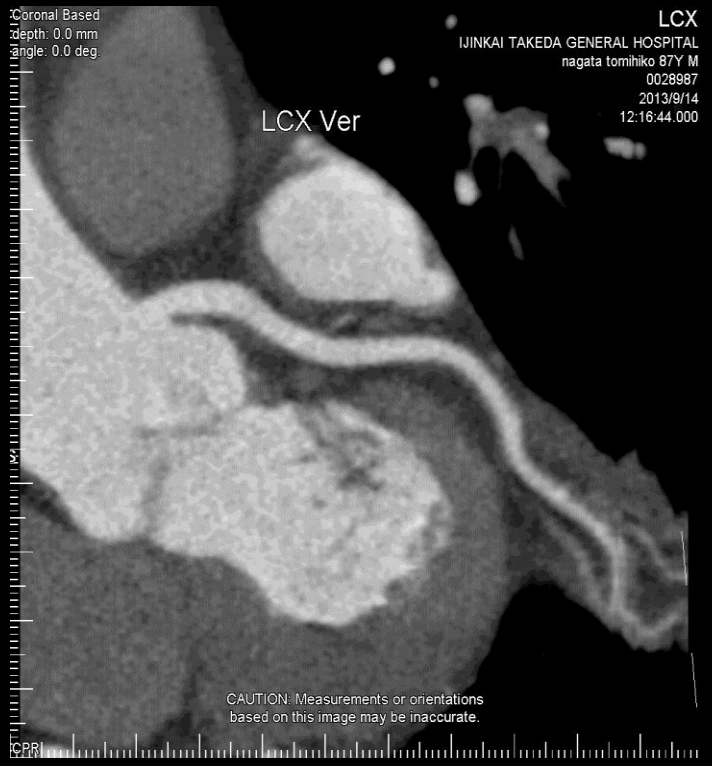
RCA




LAD




LCX



# Clinical course

- Stable hemodynamics after tapering NAd

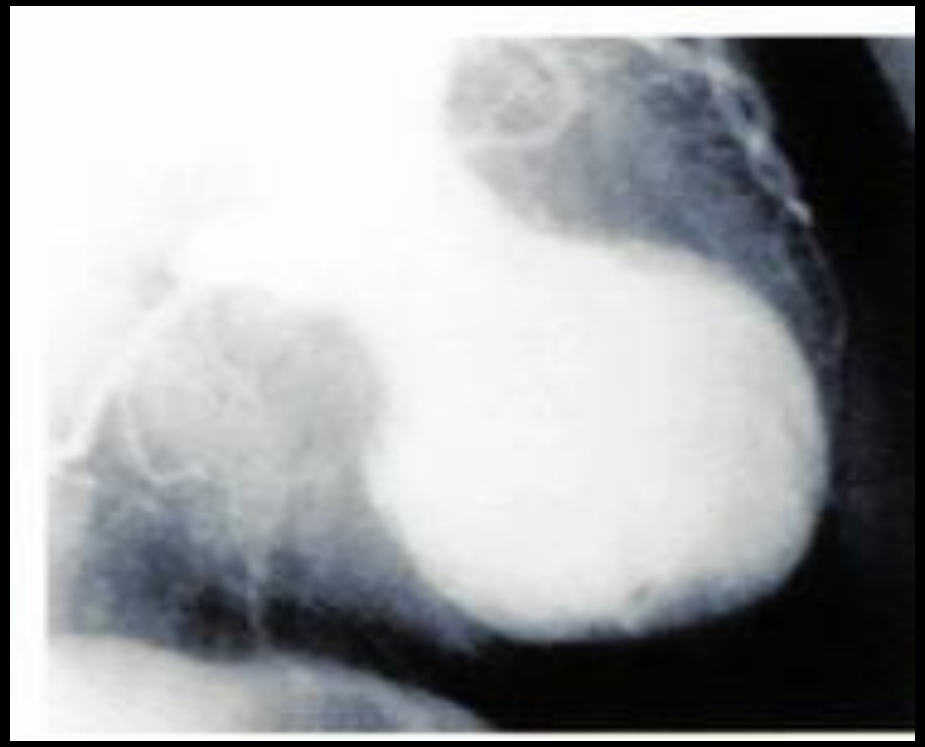
  ➡given carvedilol(2.5mg/day) and enalapril(2.5mg/day)
- No recurrence of tachycardia
- Recovered consciousness without neurological deficit on the day 4
- Rhabdomyolysis, DIC: treated without complication
- Complete recovery of LV wall motion on the day 14

# UCG after recovery



# Stress-induced (Takotsubo) cardiomyopathy

- First report by Japanese doctors in 1985
- Named after Japanese octopus trap





# Clinical features

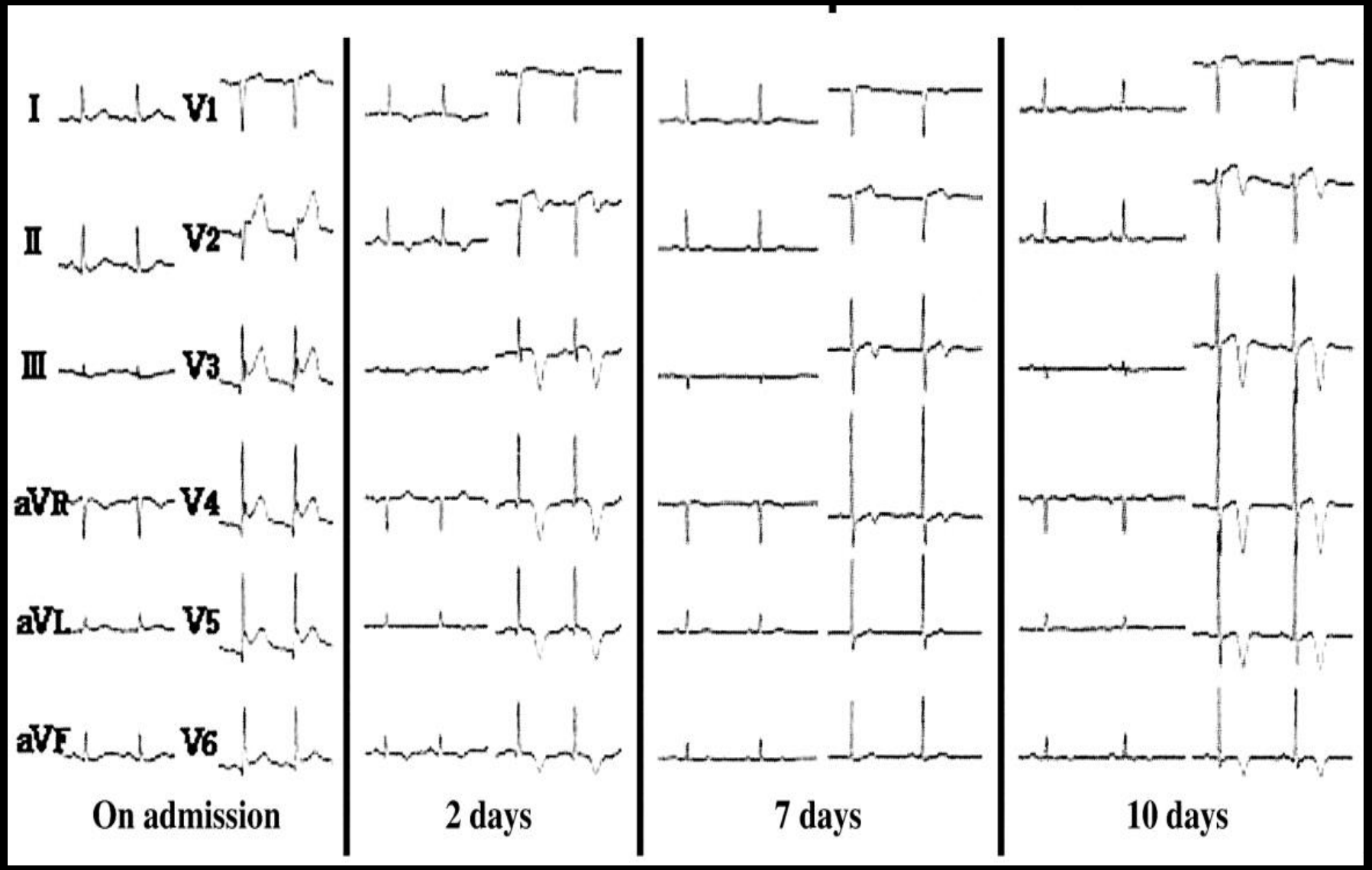
Usually occurs in postmenopausal women

Trigger: Emotional stress mostly in women

Physical stress mostly in men

Common symptom: chest pain, chest discomfort, dyspnea

# Typical time course of ECG in TTC



# Diagnosis

**Mayo clinic criteria**

1)Transient hypokinesis, akinesis, or dyskinesis of the left ventricular mid segments with or without apical involvement; the regional wall motion abnormalities extend beyond a single epicardial vascular distribution; a stressful trigger is often, but not always , present

2)Absence of  obstructive coronary disease or angiographic evidence of acute plaque rupture

3)New electrocardiographic abnormalities(either ST-segment elevation and /or T-wave inversion) or modest elevation in cardiac troponin

4)Absence of pheochromocytoma, myocarditis

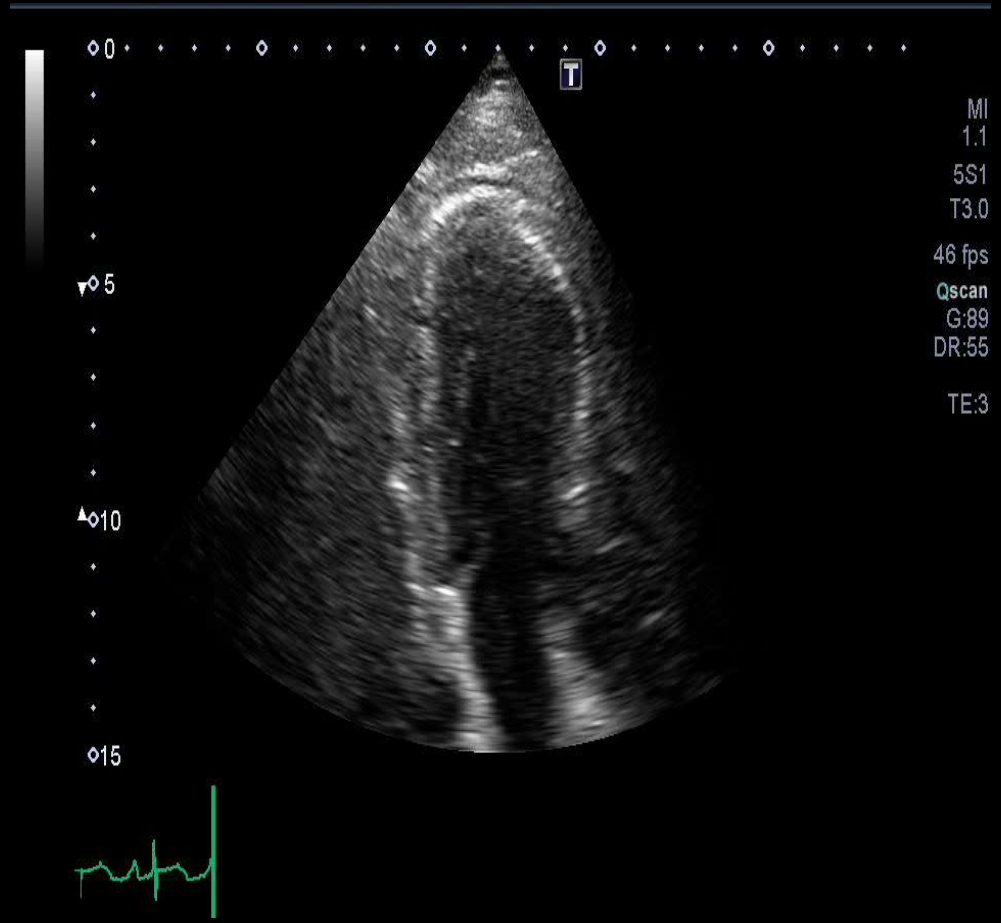
# Pathophysiology

1) Vasospasm of coronary arteries
2) Disturbance of the microcirculation
3) Catecholamine toxicity
4) Obstruction of the LVOT
5) Estrogen deficiency

# Complication and Management

- Cardiogenic shock(6.5%), congestive heart failure(3.8%)
  ➡inotropic  agent, intra-aortic balloon pumping
- apical thrombus formation, stroke
  ➡Consider anticoagulation to prevent thrombus formation
- Left ventricular rupture
- Ventricular tachycardia(1.6%), ventricular fibrillation, TdP
  ➡immediate cardioversion, correct other factors causing QT interval prolongation
- Persistent left ventricular wall motion abnormality
  ➡β-blocker, ACE-I?

# LVOTO & MR in TTC



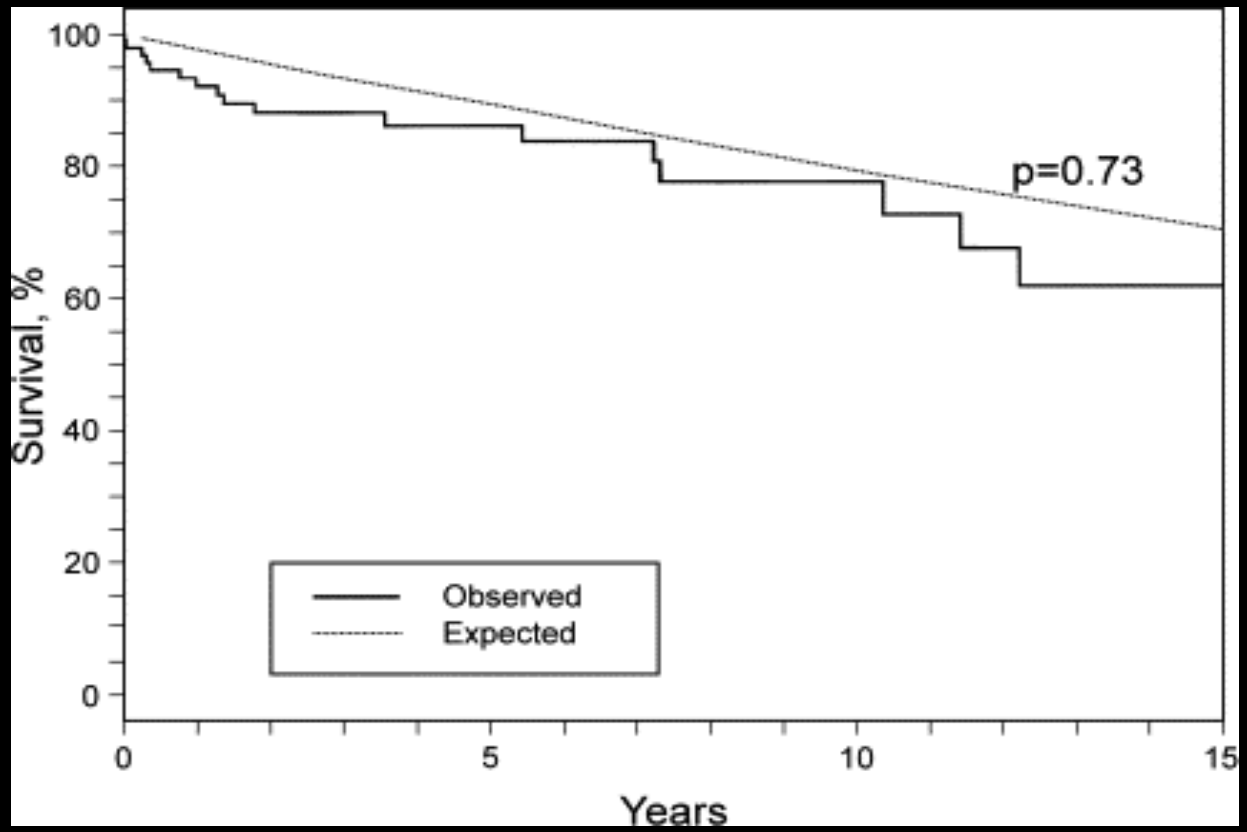



# Complication and Management

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- apical thrombus formation, stroke
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- Left ventricular rupture
- Ventricular tachycardia(1.6%), ventricular fibrillation, TdP
  ➡immediate cardioversion, correct other factors causing QT interval prolongation
- Persistent left ventricular wall motion abnormality
  ➡β-blocker, ACE-I?

# Prognosis

- Overall favorable outcome, almost complete recovery in 96%
- In hospital mortality 1.1-2%, recurrence rate11.4%




AA Elesber et al, JACC 50:2007

# Case 2 ( AMI )

Case: 67 years old, Japanese female

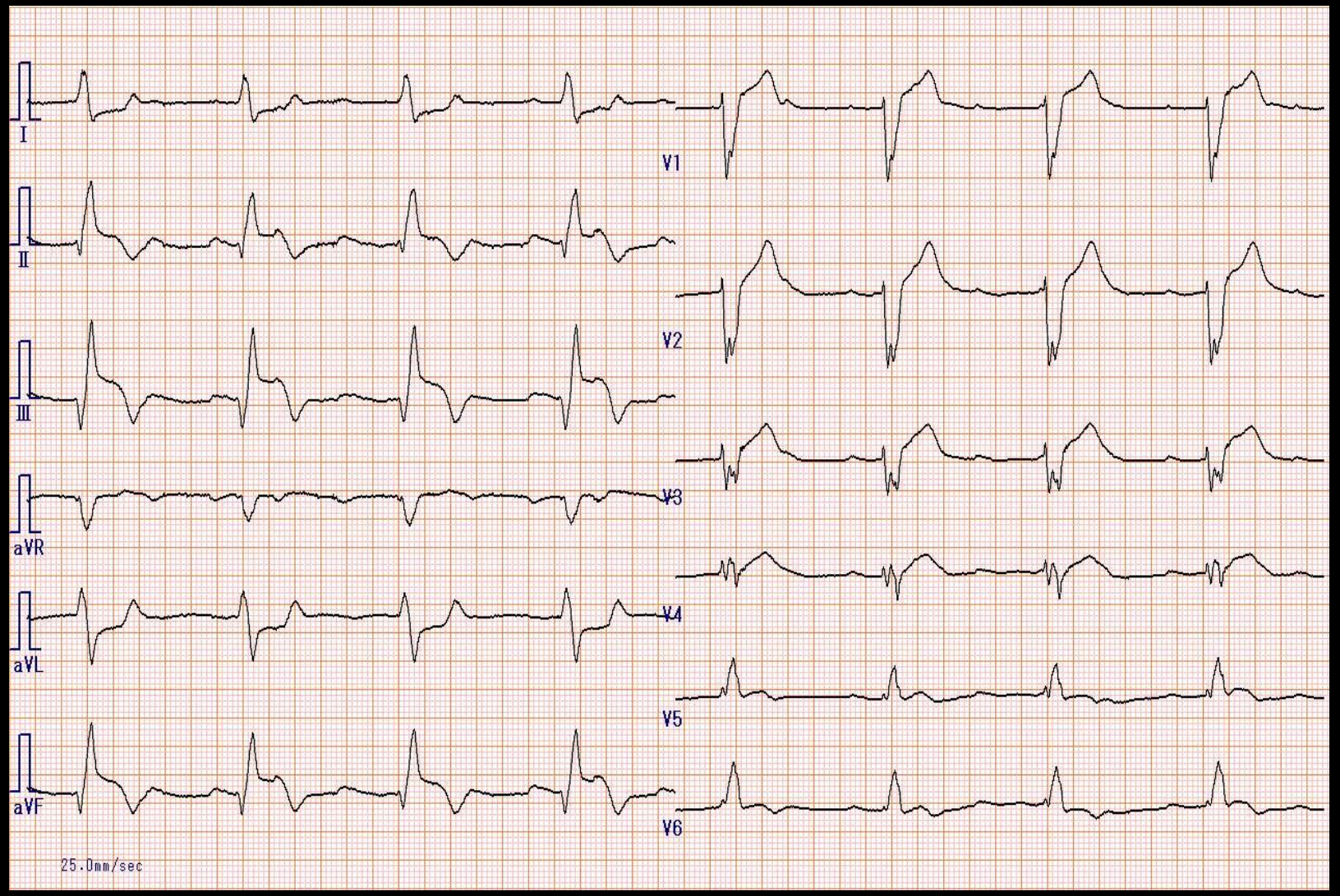
C.C.: lethargy, vomiting, abdominal pain

P.I.: She has no medical or health check history. She had lost appetite and felt lethargy recently. On the day of admission in July, she had been working outside from the morning. In the afternoon, she was transferred to our hospital for fever, vomiting and abdominal pain.

P.H.: none

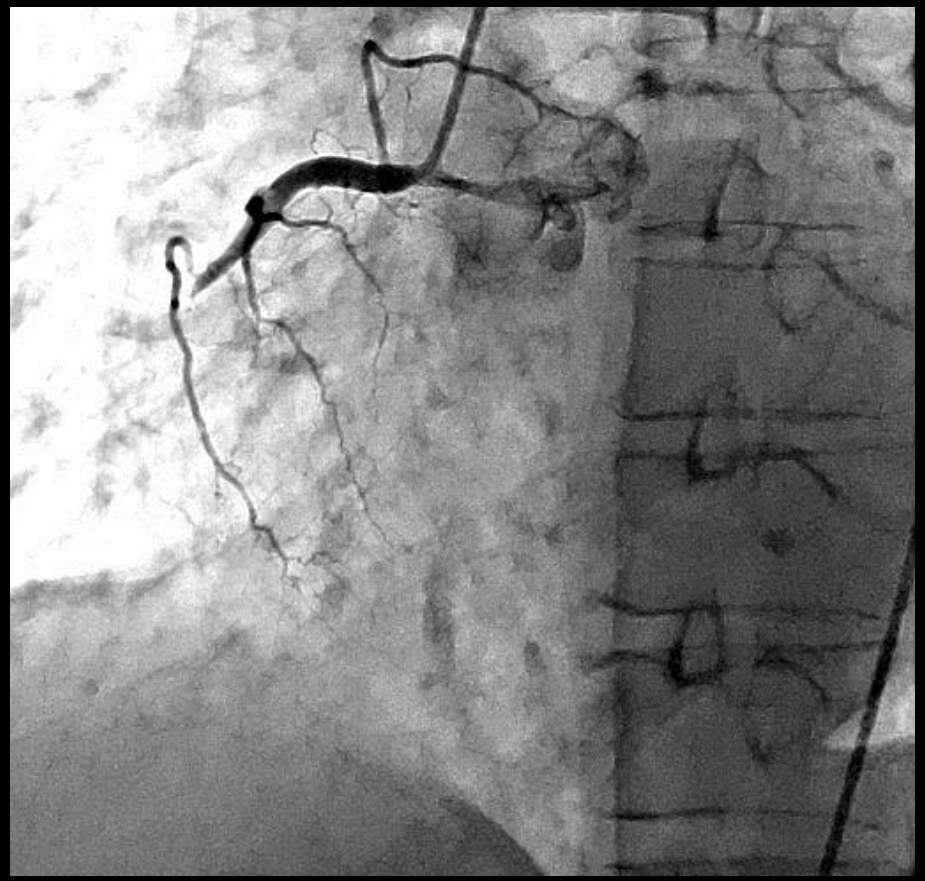
Physical exam.: consciousness , BT 38.8℃, pulse 48bpm reg, BP 124/88, chest & abdomen; unremarkable

# 12-lead ECG



# CAG

RCA

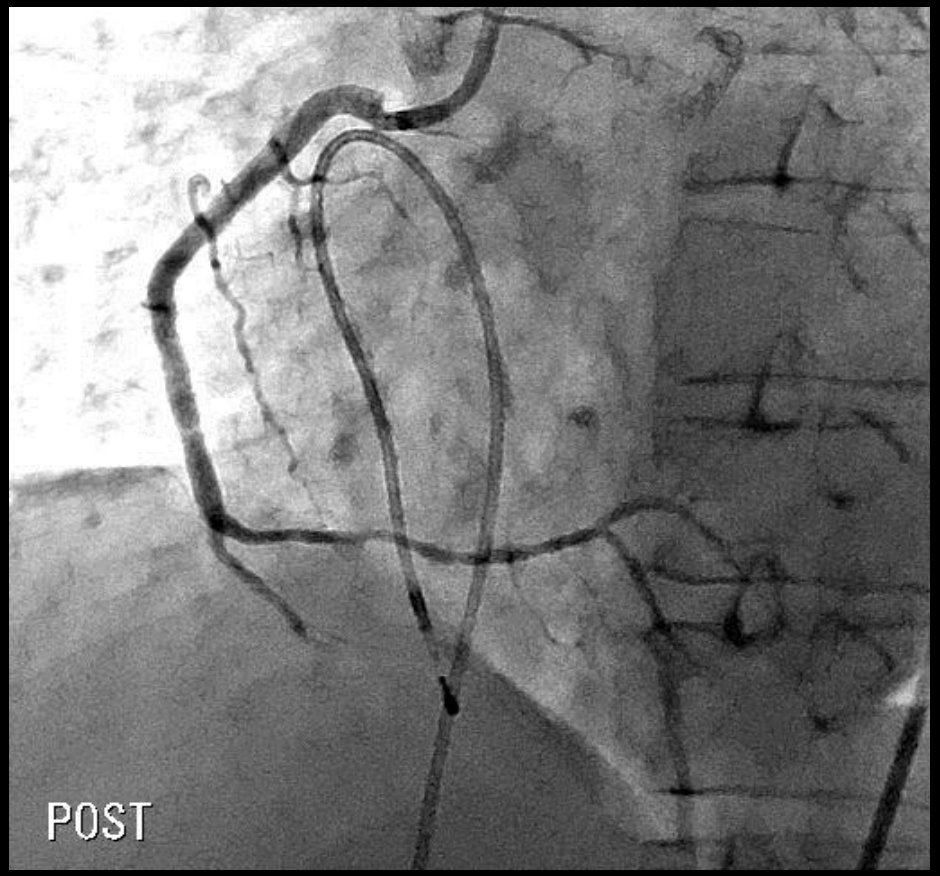


LCA

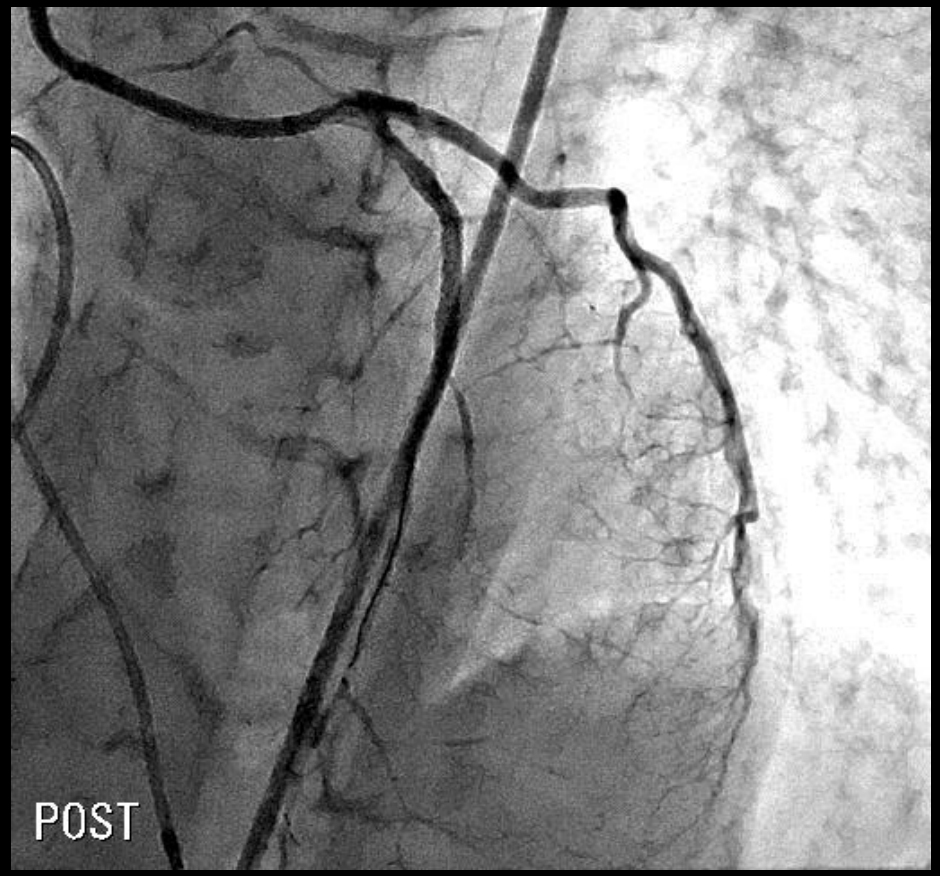


# CAG after PCI

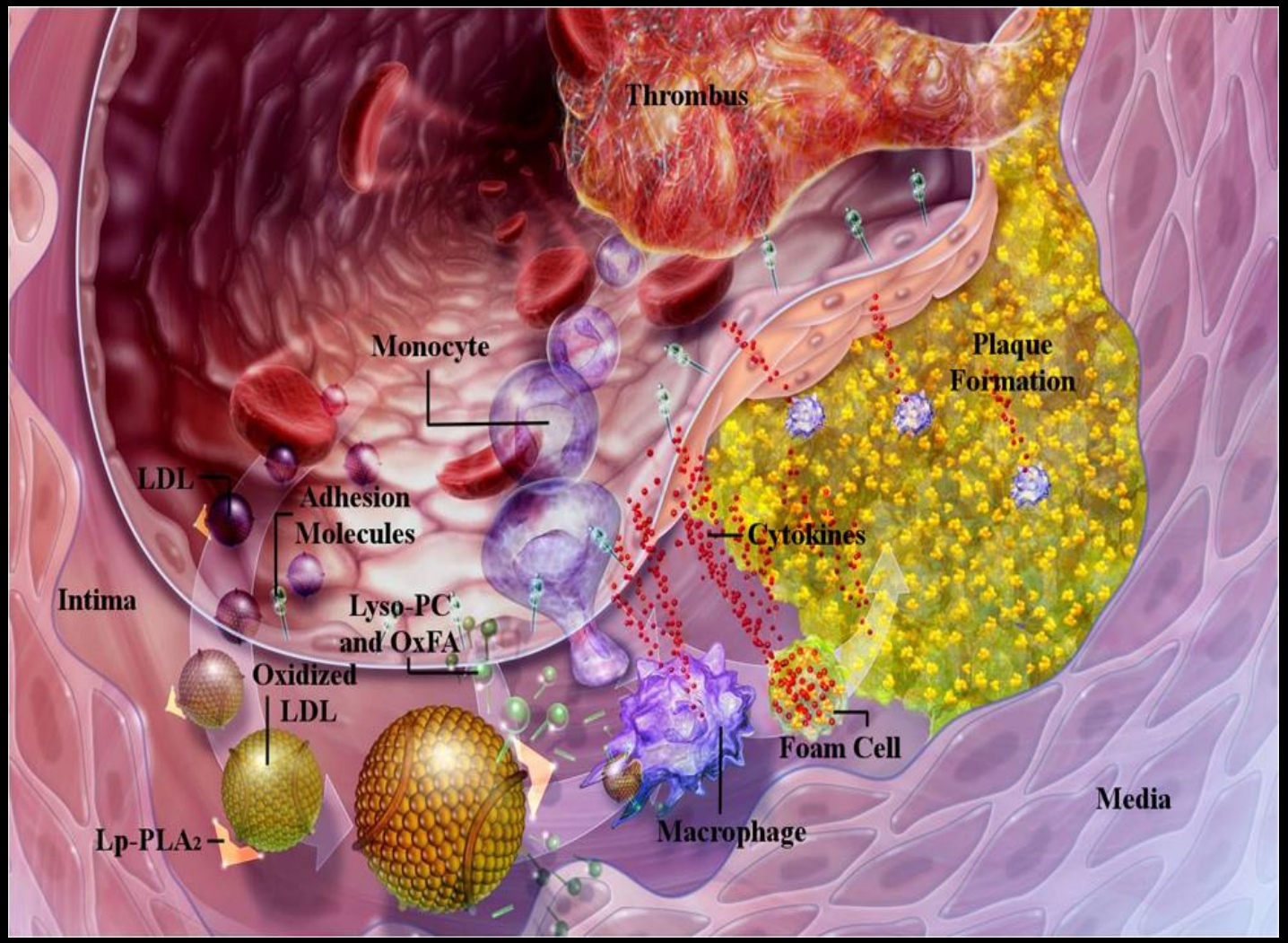
RCA




LCA



# Pathology of plaque rupture



# Conclusion

- Heat-stroke is a form of hyperthermia associated with a systemic inflammatory response leading to a syndrome of multi-organ dysfunction, accompanied by considerable increase in morbidity and mortality.
- Systemic inflammation, coagulopathy, and increased level of catecholamine in heat stroke may be related to development of cardiovascular abnormality.
- Cardiovascular events might contribute significantly to mortality in patients with heat stroke.

# Take home message

- Heat stroke can cause multiple organ failure and the presentation of circulatory failure in heat stroke may be the sign of myocardial dysfunction.
- To distinguish acute coronary syndrome and stress-induced cardiomyopathy, both of which could be evoked by heat stroke, the evaluation of coronary artery is necessary.
- Stress-induced cardiomyopathy may cause lethal arrhythmia or circulatory collapse in acute phase.
- Invasive circulatory monitoring is recommended in the patients with severe heat stroke.

# Department of Cardiology

Staff: medical doctors 10, clinical engineers 7,Nurses
ICU: 10 beds,　　Cardiology ward: 54 beds
CT：320 row area detector (Toshiba）
MRI:　2
Echocardiographic machine:5
Cardiac catheterization laboratory: 2 rooms
（Cineangiogram: Toshiba：biplane 1, single plane 1）
　　IABP　2（+α）、PCPS　2、IVUS 、OCT
Respirator: 12
CHDF　3（HD10beds）
SAS related：PSG, CPAP,  ASV

# Heat Illnesses

Heat related illnesses:

by exposure without alteration of hypothalamic thermoregulation

Fever:

by changes to the hypothalamic set point  by pyrogenic condition

<Types of Heat illnesses>

Heat edema, Heat rash, Heat cramps

Heat tetany, Heat syncope, Heat exhaustion

Heat stroke

# Heat stroke

<Risk factor>

Environmental factors

Medications

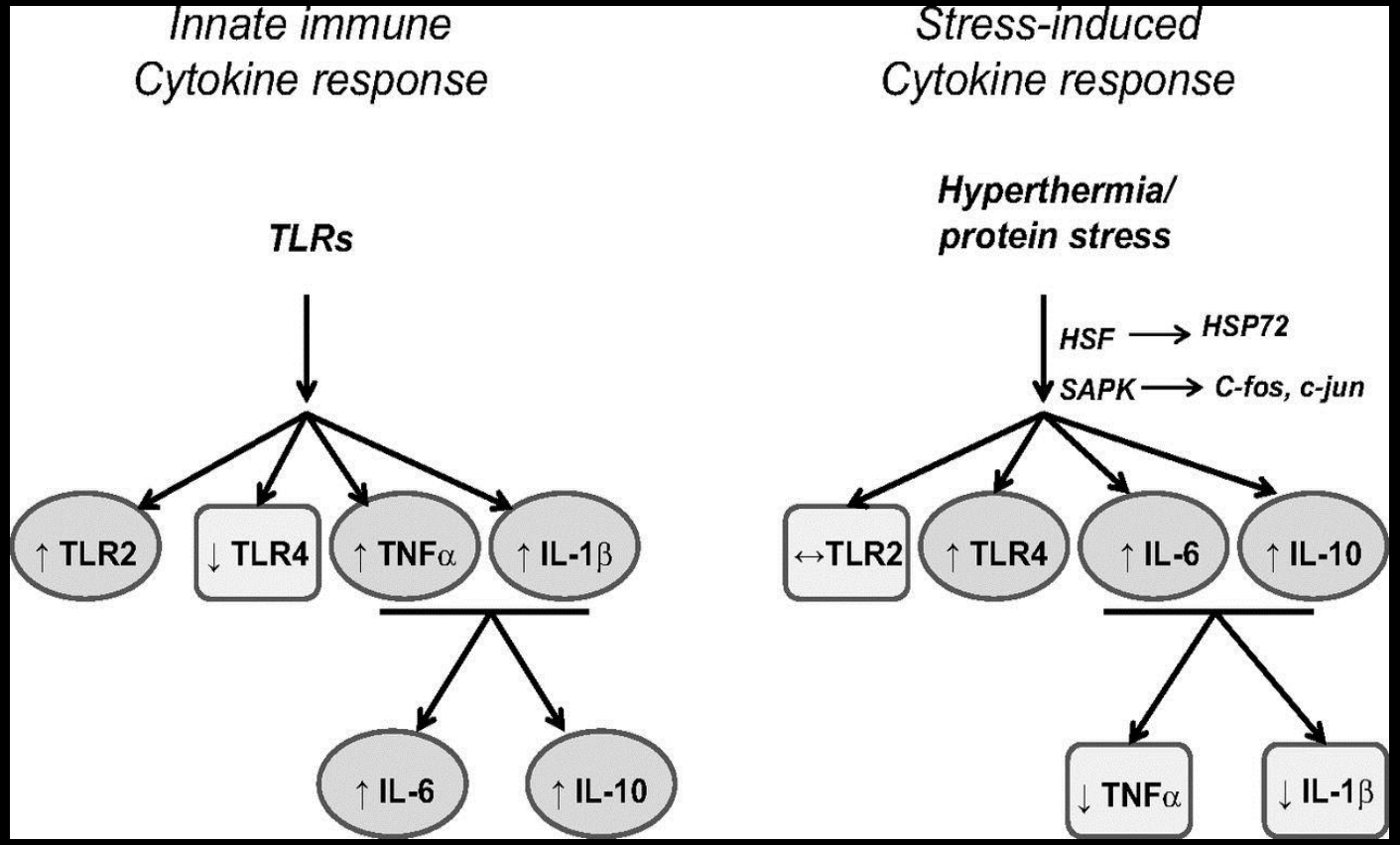
Drug use

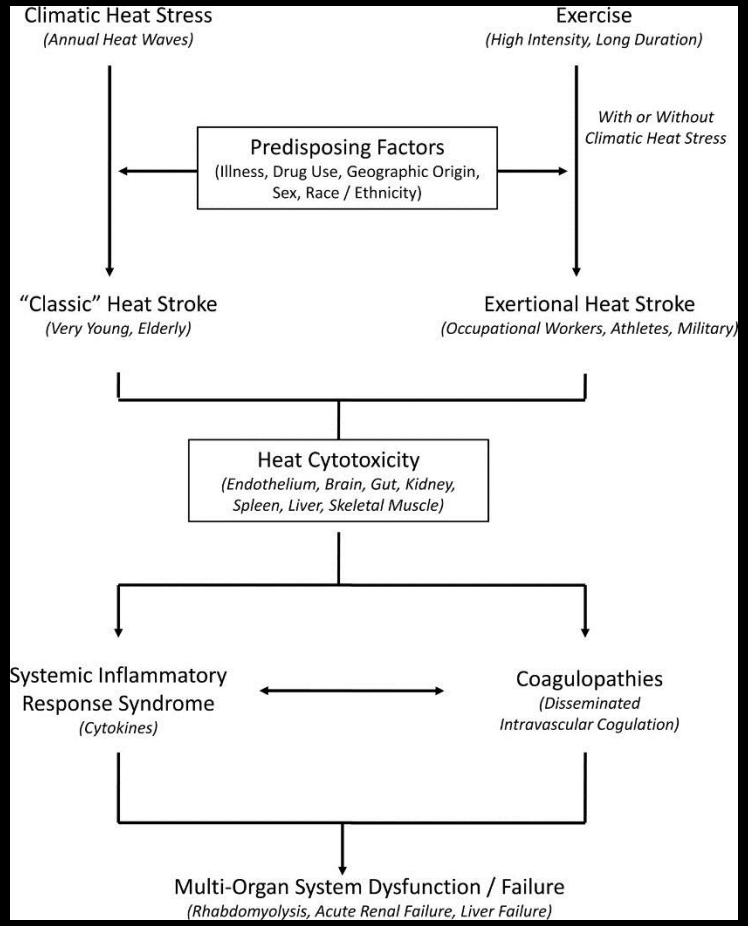
Compromised health status (elderly, cardiovascular disease)

Genetic conditions

# Differential Diagnosis in hyperthermia

| | |
|---|---|
| Endocrine | Pheochromocytoma, Thyroid storm |
| Infectious | Brain absess, Encephalitis, Meningitis<br>Malaria, Sepsis, Tetanus, Typhoid fever |
| Neurologic | CVA, Seizures |
| Toxicological | Alcohol withdrawal, Anticholinergic toxidromes<br>Aspirin overdose, Malignant hyperthermia<br>MAO inhibitors, Malignant syndrome,<br>Serotonin syndrome |


Innate immune
Cytokine response
TLRs
↑ TLR2
↓ TLR4
↑ TNFα
↑ IL-1β
↑ IL-6
↑ IL-10
Stress-induced
Cytokine response
Hyperthermia/
protein stress
HSF → HSP72
SAPK → C-fos, c-jun
↔TLR2
↑ TLR4
↑ IL-6
↑ IL-10
↓ TNFα
↓ IL-1β


Climatic Heat Stress
(Annual Heat Waves)
Exercise
(High Intensity, Long Duration)
With or Without
Climatic Heat Stress
Predisposing Factors
(Illness, Drug Use, Geographic Origin,
Sex, Race / Ethnicity)
"Classic" Heat Stroke
(Very Young, Elderly)
Exertional Heat Stroke
(Occupational Workers, Athletes, Military)
Heat Cytotoxicity
(Endothelium, Brain, Gut, Kidney,
Spleen, Liver, Skeletal Muscle)
Systemic Inflammatory
Response Syndrome
(Cytokines)
Coagulopathies
(Disseminated
Intravascular Cogulation)
Multi-Organ System Dysfunction / Failure
(Rhabdomyolysis, Acute Renal Failure, Liver Failure)

# Prevention

1. Assessment of environmental heat safety

   Wet bulb globe temperature (WBGT index)

   Equation: heat, humidity, ambient temperature, wind, reflected heat,

2. Good physical conditioning

3. Acclimatization

# Acclimatization

Takes several weeks

- Enhancement of cardiovascular performance
- Activation of the renin-angiotensin-aldosterone axis
- Increase in the capacity to secrete sweat
- Salt conservation by the sweat glands and kidneys
- Expansion of plasma volume
- Increase in the glomerular filtration rate
- Increase in the resistance to exertional rhabdomyolysis

# Management of heat stroke

1. Out of hospital

Measure the patient’s core temperature

If >40℃

→move the patient to a cooler place, remove clothing, external cooling(cold pack, fanning, spraying of the skin with water)

Clear the airway, oxygen at 4L/min, isotonic crystal(normal saline)

Transfer to the emergency department

# Management of heat stroke

2. In hospital

<Cooling period>

Hyperthermia→continue cooling

Seizures→Give benzodiazepines

Respiratory failure→consider  intubation

Hypotension→Administer fluids(Rehydration), vasopressors,
monitoring central venous pressures

Rhabdomyolysis→Volume expansion with normal saline, intravenous furosemide, mannitol,
sodium bicarbonate

Monitor serum potassium calcium, treat hyperkalemia

<After cooling>

Multi-organ dysfunction: supportive therapy

# Methods of cooling

1)Water immersion therapy

cooling rate: 0.12-0.35℃/min in ice water(<3℃）

0.04-0.25℃ in cold water(>8℃）

until core temperature reaches 38.8-38.6℃

2)Mist and fan technique

cooling rate: 0.05-0.14℃/min

3)Ice pack and internal cooling

Ice pack on the groin, axillae, neck, head

gastric, bladder, rectal lavage

4)Cooling blanket

5)Intravascular cooling device(Cool line or Icy catheter with Coolgard system)

# Case 1 ( TTC )

P.H.: 27y.o. colon volvulus, Epilepsy & HTN, leg phlegmon

Medication: none

L.H.: alcohol 50mg/day,  non-smoker

Lived in a house without air-conditioning

# Laboratory Data

1.CBC: WBC 16400,RBC 479x104,Hb 14.8,Htc 40.2,Plat 15.3x104

2.Serum Chemistry: T.prot 7.1g/dl, Alb 3.7g/dl, GOT 341U/L, GPT 139 U/L, LDH 973U/L, Al-P 315U/L, γ-GTP 82U/L, CPK 2966U/L(CPK-MB317) BUN 24mg/dl, Cr 2.0mg/dl, UA 8.9mg/dl, Na 126mEq/L, K 6.1mEq/L, BS 667mg/dl, PT(INR) 1.06, APTT 29.7sec, CRP 0.54mg/dl

3.Arterial blood gas(O2 Mask 10L): pH 7.15, Po2 97.4mmHg, Pco2 24.7 mmHg, Hco3 8.7mM/L, BE -18.9mM/L, Sat O2 95.0%, AG 15.7mM/L

4.ECG:Sinus tachycardia, Complete A-V block, q wave & ST elevation in Ⅱ, Ⅲ,aVF

5.Chest X-ray: cardiomegaly and pulmonary congestion