Cardiac Ca^{2+} Dynamics: The Roles of Ryanodine Receptor Adaptation and Sarcoplasmic Reticulum Load

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Model Equations

Ca^{2+} Subsystem

$$J_{rel} = v_1(P_{O_1} + P_{O_2})([Ca^{2+}]_{JSR} - [Ca^{2+}]_{ss}), \tag{1}$$

$$J_{leak} = v_2([Ca^{2+}]_{NSR} - [Ca^{2+}]_i), \tag{2}$$

$$J_{up} = v_3 \frac{[Ca^{2+}]_i^2}{K_{m,up}^2 + [Ca^{2+}]_i^2}, \tag{3}$$

$$J_{tr} = \frac{[Ca^{2+}]_{NSR} - [Ca^{2+}]_{JSR}}{\tau_{tr}}, \tag{4}$$

$$J_{xfer} = \frac{[Ca^{2+}]_{ss} - [Ca^{2+}]_i}{\tau_{xfer}}, \tag{5}$$

$$
\begin{aligned}
J_{trpn} &= k^{+}_{htrpn}[Ca^{2+}]_i([HTRPN]_{tot}-[HTRPNCa])-k^{-}_{htrpn}[HTRPNCa] \qquad (6)\\
&+ k^{+}_{ltrpn}[Ca^{2+}]_i([LTRPN]_{tot}-[LTRPNCa])-k^{-}_{ltrpn}[LTRPNCa],
\end{aligned}
$$

$$
\begin{aligned}
B_i &= \left\{1+\frac{[CMDN]_{tot}K_m^{CMDN}}{(K_m^{CMDN}+[Ca^{2+}]_i)^2}\right\}^{-1}, \qquad (7)\\
B_{ss} &= \left\{1+\frac{[CMDN]_{tot}K_m^{CMDN}}{(K_m^{CMDN}+[Ca^{2+}]_{ss})^2}\right\}^{-1}, \qquad (8)\\
B_{JSR} &= \left\{1+\frac{[CSQN]_{tot}K_m^{CSQN}}{(K_m^{CSQN}+[Ca^{2+}]_{JSR})^2}\right\}^{-1}. \qquad (9)
\end{aligned}
$$

$$
\frac{d[Ca^{2+}]_i}{dt}=B_i\left\{J_{leak}+J_{xfer}-J_{up}-J_{trpn}-(I_{Ca,b}-2I_{NaCa}+I_{p(Ca)})\frac{A_{cap}}{2V_{myo}F}\right\}, \qquad (10)
$$

$$
\frac{d[Ca^{2+}]_{ss}}{dt}=B_{ss}\left\{J_{rel}\frac{V_{JSR}}{V_{ss}}-J_{xfer}\frac{V_{myo}}{V_{ss}}-(I_{Ca})\frac{A_{cap}}{2V_{ss}F}\right\}. \qquad (11)
$$

$$
\begin{aligned}
\frac{d[Ca^{2+}]_{JSR}}{dt} &= B_{JSR}\left\{J_{tr}-J_{rel}\right\}, \qquad (12)\\
\frac{d[Ca^{2+}]_{NSR}}{dt} &= \left\{J_{up}-J_{leak}\right\}\frac{V_{myo}}{V_{NSR}}-J_{tr}\frac{V_{JSR}}{V_{NSR}}. \qquad (13)
\end{aligned}
$$

L-type Ca^{2+} channel

$$
\begin{aligned}
\alpha &= 0.4e^{(V+12)/10} \qquad (14)\\
\beta &= 0.05e^{-(V+12)/13} \qquad (15)\\
\alpha' &= \alpha a \qquad (16)\\
\beta' &= \frac{\beta}{b} \qquad (17)\\
\gamma &= 0.1875[Ca^{2+}]_{ss}, \qquad (18)
\end{aligned}
$$

$$
\begin{aligned}
\frac{dC_0}{dt} &= \beta C_1 + \omega C_{Ca0} - (4\alpha + \gamma)C_0 && (19)\\
\frac{dC_1}{dt} &= 4\alpha C_0 + 2\beta C_2 + \frac{\omega}{b}C_{Ca1} - (\beta + 3\alpha + \gamma a)C_1 && (20)\\
\frac{dC_2}{dt} &= 3\alpha C_1 + 3\beta C_3 + \frac{\omega}{b^2}C_{Ca2} - (2\beta + 2\alpha + \gamma a^2)C_2 && (21)\\
\frac{dC_3}{dt} &= 2\alpha C_2 + 4\beta C_4 + \frac{\omega}{b^3}C_{Ca3} - (3\beta + \alpha + \gamma a^3)C_3 && (22)\\
\frac{dC_4}{dt} &= \alpha C_3 + gO + \frac{\omega}{b^4}C_{Ca4} - (4\beta + f + \gamma a^4)C_4 && (23)\\
\frac{dO}{dt} &= fC_4 - gO && (24)\\
\frac{dC_{Ca0}}{dt} &= \beta' C_{Ca1} + \gamma C_0 - (4\alpha' + \omega)C_{Ca0} && (25)\\
\frac{dC_{Ca1}}{dt} &= 4\alpha' C_{Ca0} + 2\beta' C_{Ca2} + \gamma a C_1 - (\beta' + 3\alpha' + \frac{\omega}{b})C_{Ca1} && (26)\\
\frac{dC_{Ca2}}{dt} &= 3\alpha' C_{Ca1} + 3\beta' C_{Ca3} + \gamma a^2 C_2 - (2\beta' + 2\alpha' + \frac{\omega}{b^2})C_{Ca2} && (27)\\
\frac{dC_{Ca3}}{dt} &= 2\alpha' C_{Ca2} + 4\beta' C_{Ca4} + \gamma a^3 C_3 - (3\beta' + \alpha' + \frac{\omega}{b^3})C_{Ca3} && (28)\\
\frac{dC_{Ca4}}{dt} &= \alpha' C_{Ca_3} + g' O_{Ca} + \gamma a^4 C_4 - (4\beta' + f' + \frac{\omega}{b^4})C_{Ca4} && (29)\\
\frac{dO_{Ca}}{dt} &= f' C_{Ca4} - g' O_{Ca}. && (30)
\end{aligned}
$$

$$
\frac{dy}{dt} = \frac{y_\infty - y}{\tau_y}, \tag{31}
$$

$$
y_\infty = \frac{1}{1 + e^{(V+55)/7.5}} + \frac{0.1}{1 + e^{(-V+21)/6}}, \tag{32}
$$

$$
\tau_y = 20 + \frac{600}{1 + e^{(V+30)/9.5}}. \tag{33}
$$

$$
P_{K'} = \frac{\overline{P}_K}{1 + \frac{I_{Ca_{max}}}{I_{Ca_{half}}}}, \tag{34}
$$

$$I_{Ca_{max}} = \overline{P}_{Ca} 4 \frac{VF^2}{RT} \frac{0.001 e^{2VF/RT} - 0.341[Ca]_o}{e^{2VF/RT} - 1}, \tag{35}$$

$$I_{Ca} = y\{O + O_{Ca}\} I_{Ca_{max}}, \tag{36}$$

$$I_{Ca,K} = P'_K y\{O + O_{Ca}\} \frac{VF^2}{RT} \frac{[K^+]_i e^{VF/RT} - [K^+]_o}{e^{VF/RT} - 1}. \tag{37}$$

Appendix

1 Ionic Currents (Luo and Rudy)

1.1 Differential Equations

$$\begin{aligned}
\frac{dV}{dt} &= \frac{-1}{C_m}(I_{Na} + I_{Ca} + I_K + I_{K_1} + I_{Kp} + I_{NaCa} + I_{NaK} + I_{ns(Ca)} + I_{p(Ca)} \qquad (38)\\
&+ I_{Ca,K} + I_{Ca,b} + I_{Na,b})\\
\frac{dm}{dt} &= \alpha_m(1-m) - \beta_m m \qquad (39)\\
\frac{dh}{dt} &= \alpha_h(1-h) - \beta_h h \qquad (40)\\
\frac{dj}{dt} &= \alpha_j(1-j) - \beta_j j \qquad (41)\\
\frac{dx}{dt} &= \alpha_x(1-x) - \beta_x x \qquad (42)\\
\frac{d[Na^+]_i}{dt} &= -(I_{Na} + I_{Na,b} + I_{ns,Na} + 3I_{NaCa} + 3I_{NaK})\frac{A_{cap}}{V_{myo}F} \qquad (43)\\
\frac{d[K^+]_i}{dt} &= -(I_K + I_{K_1} + I_{Kp} + I_{ns,K} - 2I_{NaK} + I_{Ca,K})\frac{A_{cap}}{V_{myo}F} \qquad (44)\\
\frac{d[HTRPNCa]}{dt} &= k^+_{htrpn}[Ca^{2+}]_i([HTRPN]_{tot} - [HTRPNCa]) - k^-_{htrpn}[HTRPNCa] \qquad (45)\\
\frac{d[LTRPNCa]}{dt} &= k^+_{ltrpn}[Ca^{2+}]_i([LTRPN]_{tot} - [LTRPNCa]) - k^-_{ltrpn}[LTRPNCa] \qquad (46)
\end{aligned}$$

1.2 Fast Na$^+$ current

$$I_{Na} = \overline{G}_{Na} m^3 hj(V - E_{Na}) \tag{47}$$

$$E_{Na} = \frac{RT}{F} ln\Big(\frac{[Na^+]_o}{[Na^+]_i}\Big) \tag{48}$$

$$\alpha_m = 0.32 \frac{V + 47.13}{1 - e^{-0.1(V+47.13)}} \tag{49}$$

$$\beta_m = 0.08 e^{\frac{-V}{11}} \tag{50}$$

For $v \geq -40\ mV$,

$$\alpha_h = 0.0 \tag{51}$$

$$\alpha_j = 0.0 \tag{52}$$

$$\beta_h = \frac{1}{0.13(1 + e^{(V+10.66)/-11.1})} \tag{53}$$

$$\beta_j = 0.3 \frac{e^{-2.535 \times 10^{-7} V}}{1 + e^{-0.1(V+32)}} \tag{54}$$

For $v < -40\ mV$,

$$\alpha_h = 0.135 e^{(80+V)/-6.8} \tag{55}$$

$$\alpha_j = \Big(-127140 e^{0.2444V} - 3.474 \times 10^{-5} e^{-0.04391V}\Big) \frac{V + 37.78}{1 + e^{0.311(V+79.23)}} \tag{56}$$

$$\beta_h = 3.56 e^{0.079V} + 3.1 \times 10^5 e^{0.35V} \tag{57}$$

$$\beta_j = 0.1212 \frac{e^{-0.01052V}}{1 + e^{-0.1378(V+40.14)}} \tag{58}$$

1.3 Time-dependent K$^+$ current I_K

$$I_K = \overline{G}_K X_i X^2 (V - E_K) \tag{59}$$

$$E_K = \frac{RT}{F} ln\Big(\frac{[K^+]_o + P_{Na,K}[Na^+]_o}{[K^+]_i + P_{Na,K}[Na^+]_i}\Big) \tag{60}$$

$$\overline{G}_K = 0.1128 \sqrt{\frac{[K^+]_o}{5.4}} \tag{61}$$

$$X_i = \frac{1}{1+e^{(V-56.26)/32.1}} \tag{62}$$

$$\alpha_X = 7.19 \times 10^{-5} \frac{V+30}{1-e^{-0.148(V+30)}} \tag{63}$$

$$\beta_X = 1.31 \times 10^{-4} \frac{V+30}{-1+e^{0.0687(V+30)}} \tag{64}$$

1.4 Time-independent K$^+$ current I_{K_1}

$$I_{K_1} = \overline{G}_{K_1} K_{1_\infty}(V - E_{K_1}) \tag{65}$$

$$E_{K_1} = \frac{RT}{F} ln\Big(\frac{[K^+]_o}{[K^+]_i}\Big) \tag{66}$$

$$\overline{G}_{K_1} = 0.75\sqrt{\frac{[K^+]_o}{5.4}} \tag{67}$$

$$K_{1_\infty} = \frac{\alpha_{K_1}}{\alpha_{K_1} + \beta_{K_1}} \tag{68}$$

$$\alpha_{K_1} = \frac{1.02}{1+e^{0.2385(V-E_{K_1}-59.215)}} \tag{69}$$

$$\beta_{K_1} = \frac{0.4912e^{0.08032(V-E_{K_1}+5.476)} + e^{0.06175(V-E_{K_1}-594.31)}}{1+e^{-0.5143(V-E_{K_1}+4.753)}} \tag{70}$$

1.5 Plateau K$^+$ current I_{Kp}

$$I_{Kp} = \overline{G}_{Kp} K_p (V - E_{Kp}) \tag{71}$$

$$E_{Kp} = E_{K_1} \tag{72}$$

$$K_p = \frac{1}{1+e^{(7.488-V)/5.98}} \tag{73}$$

1.6 Na^{2+}-Ca^{2+} exchanger current I_{NaCa}

$$I_{NaCa} = k_{NaCa} \frac{1}{K^3_{m,Na} + [Na^+]^3_o} \frac{1}{K_{m,Ca} + [Ca^{2+}]_o} \frac{1}{1+k_{sat}e^{(\eta-1)VF/RT}} \Big(e^{\eta VF/RT} \cdot [Na^+]^3_i [Ca^{2+}]_o - e^{(\eta-1)VF/RT}[Na^+]^3_o [Ca^{2+}]_i\Big) \tag{74}$$

1.7 Na^{2+}-K^{+} pump

$$I_{NaK} = \overline{I}_{NaK} f_{NaK} \frac{1}{1+(\frac{K_{m,Nai}}{[Na^+]_i})^{1.5}} \frac{[K^+]_o}{[K^+]_o + K_{m,Ko}} \quad (75)$$

$$f_{NaK} = \frac{1}{1+0.1245e^{-0.1VF/RT} + 0.0365\sigma e^{-VF/RT}} \quad (76)$$

$$\sigma = \frac{1}{7}\left(e^{\frac{[Na^+]_o}{67.3}} - 1\right) \quad (77)$$

1.8 Nonspecific Ca^{2+}-activated current $I_{ns(Ca)}$

$$I_{ns(Ca)} = I_{ns,Na} + I_{ns,K} \quad (78)$$

$$I_{ns,Na} = \overline{I}_{ns,Na} \frac{1}{1+\left(\frac{K_{m,ns(Ca)}}{[Ca^{2+}]_i}\right)^3} \quad (79)$$

$$\overline{I}_{ns,Na} = P_{ns(Ca)} \frac{VF^2}{RT} \frac{0.75[Na^+]_i e^{VF/(RT)} - 0.75[Na^+]_o}{e^{VF/(RT)} - 1} \quad (80)$$

$$I_{ns,K} = \overline{I}_{ns,K} \frac{1}{1+\left(\frac{K_{m,ns(Ca)}}{[Ca^{2+}]_i}\right)^3} \quad (81)$$

$$\overline{I}_{ns,K} = P_{ns(Ca)} \frac{VF^2}{RT} \frac{0.75[K^+]_i e^{VF/(RT)} - 0.75[K^+]_o}{e^{VF/(RT)} - 1} \quad (82)$$

1.9 Sarcolemmal Ca^{2+} pump current $I_{p(Ca)}$

$$I_{p(Ca)} = \overline{I}_{p(Ca)} \frac{[Ca^{2+}]_i}{K_{m,p(Ca)} + [Ca^{2+}]_i} \quad (83)$$

1.10 Ca^{2+} background current $I_{Ca,b}$

$$I_{Ca,b} = \overline{G}_{Ca,b}(V - E_{Ca,N}) \quad (84)$$

$$E_{Ca,N} = \frac{RT}{2F} ln\left(\frac{[Ca^{2+}]_o}{[Ca^{2+}]_i}\right) \quad (85)$$

1.11 Na^{+} background current $I_{Na,b}$

$$I_{Na,b} = \overline{G}_{Na,b}(V - E_{Na,N}) \quad (86)$$

$$E_{Na,N} = E_{Na} \tag{87}$$

2 RyR Channel States (Keizer and Levine)

$$\frac{dP_{C_1}}{dt} = -k_a^+[Ca^{2+}]_{SS}^n P_{C_1} + k_a^- P_{O_1} \tag{88}$$

$$\frac{dP_{O_1}}{dt} = k_a^+[Ca^{2+}]_{SS}^n P_{C_1} - k_a^- P_{O_1} - k_b^+[Ca^{2+}]_{SS}^m P_{O_1} \tag{89}$$

$$+k_b^- P_{O_2} - k_c^+ P_{O_1} + k_c^- P_{C_2}$$

$$\frac{dP_{O_2}}{dt} = k_b^+[Ca^{2+}]_{SS}^m P_{O_1} - k_b^- P_{O_2} \tag{90}$$

$$\frac{dP_{C_2}}{dt} = k_c^+ P_{O_1} - k_c^- P_{C_2} \tag{91}$$

3 Tables

3.1 Table 1 - Cell Geometry Parameters

Parameter	Definition	Value
A_{cap}	capacative membrane area	$1.534 \times 10^{-4}\ cm^2$
V_{myo}	myoplasmic volume	$25.84 \times 10^{-6}\ \mu L$
V_{JSR}	junctional SR volume	$0.12 \times 10^{-6}\ \mu L$
V_{NSR}	network SR volume	$2.098 \times 10^{-6}\ \mu L$
V_{SS}	subspace volume	$1.485 \times 10^{-9}\ \mu L$

3.2 Table 2 - Standard Ionic Concentrations

Parameter	Definition	Value
$[K^+]_o$	extracellular K^+concentration	$5.4\ mM$
$[Na^+]_o$	extracellular Na^{2+} concentration	$140.0\ mM$
$[Ca^{2+}]_o$	extracellular Ca^{2+} concentration	$1.8\ mM$

3.3 Table 3 - SR Parameters

Parameter	Definition	Value
v_1	maximum RyR channel Ca^{2+} permeability	$1.8\ ms^{-1}$
v_2	Ca^{2+} leak rate constant from the NSR	$5.80 \times 10^{-5}\ ms^{-1}$
v_3	SR Ca^{2+}-ATPase maximaum pump rate	$1.8\ \mu M ms^{-1}$
$K_{m,up}$	half saturation constant for SR Ca^{2+}-ATPase pump	$0.5\ \mu M$
τ_{tr}	time constant for transfer from NSR to JSR	$34.48\ ms$
τ_{xfer}	time constant for transfer from subspace to myoplasm	$3.125\ ms$
k_a^+	RyR $P_{C_1} - P_{O_1}$ rate constant	$0.01215\ \mu M^{-4} ms^{-1}$
k_a^-	RyR $P_{O_1} - P_{C_1}$ rate constant	$0.1425\ ms^{-1}$
k_b^+	RyR $P_{O_1} - P_{O_2}$ rate constant	$0.00405\ \mu M^{-3} ms^{-1}$
k_b^-	RyR $P_{O_2} - P_{O_1}$ rate constant	$1.930\ ms^{-1}$
k_c^+	RyR $P_{O_1} - P_{C_2}$ rate constant	$0.018\ ms^{-1}$
k_c^-	RyR $P_{C_2} - P_{O_1}$ rate constant	$0.0008\ ms^{-1}$
n	RyR Ca^{2+} cooperativity parameter $P_{C_1} - P_{O_1}$	4
m	RyR Ca^{2+} cooperativity parameter $P_{O_1} - P_{O_2}$	3

3.4 Table 4 - L-type Ca^{2+} Channel Parameters

Parameter	Definition	Value
f	transition rate into open state	$0.3\ ms^{-1}$
g	transition rate out of open state	$2.0\ ms^{-1}$
f'	transition rate into open state for modeCa	$0.0\ ms^{-1}$
g'	transition rate out of open state	$0.0\ ms^{-1}$
a	mode transition parameter	2.0
b	mode transition parameter	2.0
ω	mode transition parameter	$0.01\ ms^{-1}$
$\overline{P}_{Ca}$	L-type Ca^{2+} channel permeability to Ca^{2+}	$33.75 \times 10^{-4}\ cm\, s^{-1}$
$\overline{P}_K$	L-type Ca^{2+} channel permeability to K^+	$62.5 \times 10^{-7}\ cm\, s^{-1}$
$I_{Ca_{half}}$	I_{Ca} level that reduces $\overline{P}_K$ by half	$-0.458\ \mu A \mu F^{-1}$

3.5 Table 5 - Buffering Parameters

Parameter	Definition	Value
$[LTRPN]_{tot}$	total myoplasmic troponin low affinity site concentration	$70.0\ \mu M$
$[HTRPN]_{tot}$	total myoplasmic troponin high affinity site concentration	$140.0\ \mu M$
k^+_{htrpn}	Ca^{2+} on rate constant for troponin high affinity sites	$2.0 \times 10^7\ M^{-1}s^{-1}$
k^-_{htrpn}	Ca^{2+} off rate constant for troponin high affinity sites	$0.066\ s^{-1}$
k^+_{ltrpn}	Ca^{2+} on rate constant for troponin low affinity sites	$4.0 \times 10^7\ M^{-1}s^{-1}$
k^-_{ltrpn}	Ca^{2+} on rate constant for troponin low affinity sites	$40.0\ s^{-1}$
$[CMDN]_{tot}$	total myoplasmic calmodulin concentration	$50.0\ \mu M$
$[CSQN]_{tot}$	total network SR calsequestrin concentration	$15.0\ mM$
K_m^{CMDN}	Ca^{2+} half saturation constant for calmodulin	$2.38\ \mu M$
K_m^{CSQN}	Ca^{2+} half saturation constant for calsequestrin	$0.8\ mM$

3.6 Table 6 - Membrane Current Parameters

Parameter	Definition	Value
C_m	unit membrane capacitance	$1.0\ \mu F\, cm^{-2}$
F	Faraday's constant	$96.5\ coul\, mmol^{-1}$
T	absolute temperature	$310\ K$
R	ideal gas constant	$8.314\ Jmol^{-1}K^{-1}$
$\overline{G}_{Na}$	maximum Na^+ channel conductance	$12.8\ mS\mu F^{-1}$ (16.0)
$\overline{G}_{Kp}$	maximum plateau K^+ channel conductance	$0.00828\ mS\mu F^{-1}$ (0.0183)
$P_{Na,K}$	Na^+ permeability of K^+ channel	0.01833
k_{NaCa}	scaling factor of Na^+-Ca^{2+} exchange	$5000\ \mu A\, \mu F^{-1}$ (2000)
$K_{m,Na}$	Na^+ half saturation constant for Na^+-Ca^{2+} exchange	$87.5\ mM$
$K_{m,Ca}$	Ca^{2+} half saturation constant for Na^+-Ca^{2+} exchange	$1.38\ mM$
k_{sat}	Na^+-Ca^{2+} exchange saturation factor at very negative potentials	0.1
η	controls voltage dependence of Na^+-Ca^{2+} exchange	0.35
$\overline{I}_{NaK}$	maximum Na^+-K^+ pump curent	$1.73\ \mu A\, \mu F^{-1}$ (1.5)
$K_{m,Nai}$	Na^+ half saturation constant for Na^+-K^+ pump	$10.0\ mM$
$K_{m,Ko}$	K^+ half saturation constant for Na^+-K^+ pump	$1.5\ mM$
$P_{ns(Ca)}$	nonspecific current channel permeability	$0.0\ cms^{-1}$ (1.75×10^{-7})
$K_{m,ns(Ca)}$	Ca^{2+} half saturation constant for nonspecific current	$1.2\ \mu M$
$\overline{I}_{p(Ca)}$	maximum sarcolemmal Ca^{2+} pump current	$1.15\ \mu A\, \mu F^{-1}$
$K_{m,p(Ca)}$	Ca^{2+} half saturation constant for sarcolemmal Ca^{2+} pump	$0.5\ \mu M$
$\overline{G}_{Ca,b}$	maximum background Ca^{2+} current conductance	$0.00201\ mS\mu F^{-1}$ (0.003016)
$\overline{G}_{Na,b}$	maximum background Na^+ current conductance	$0.00141\ mS\mu F^{-1}$

The original Luo-Rudy Phase II parameters are shown in parenthesis.

3.7 Table 7 - Initial Conditions

Variable	Definition	Initial Value
t	time	$0.00\ ms$
V	membrane potential	$-86.1638\ mV$
m	I_{Na} activation gate	3.28302×10^{-02}
h	I_{Na} inactivation gate	0.988354
j	I_{Na} slow inactivation gate	0.992540
x	I_K activation gate	9.28836×10^{-04}
$[Na^+]_i$	intracellular Na^+ concentration	$10.2042\ mM$
$[K^+]_i$	intracellular K^+ concentration	$143.727\ mM$
$[\mathrm{Ca}^{2+}]_i$	myoplasmic Ca^{2+} concentration	$9.94893 \times 10^{-05}\ mM$
$[\mathrm{Ca}^{2+}]_{NSR}$	network SR Ca^{2+} concentration	$1.24891\ mM$
$[\mathrm{Ca}^{2+}]_{ss}$	subspace SR Ca^{2+} concentration	$1.36058 \times 10^{-04}\ mM$
$[\mathrm{Ca}^{2+}]_{JSR}$	junctional SR Ca^{2+} concentration	$1.17504\ mM$
P_{C_1}	fraction of channels in state P_{C_1}	0.762527
P_{0_1}	fraction of channels in state P_{0_1}	1.19168×10^{-03}
P_{0_2}	fraction of channels in state P_{0_2}	6.30613×10^{-09}
P_{C_2}	fraction of channels in state P_{C_2}	0.236283
C_0	L-type Ca^{2+} channel closed state mode normal	0.997208
C_1	L-type Ca^{2+} channel closed state mode normal	6.38897×10^{-05}
C_2	L-type Ca^{2+} channel closed state mode normal	1.53500×10^{-09}
C_3	L-type Ca^{2+} channel closed state mode normal	1.63909×10^{-14}
C_4	L-type Ca^{2+} channel closed state mode normal	6.56337×10^{-20}
O	L-type Ca^{2+} channel conducting state mode normal	9.84546×10^{-21}
C_{Ca0}	L-type Ca^{2+} channel closed state mode Ca	2.72826×10^{-03}
C_{Ca1}	L-type Ca^{2+} channel closed state mode Ca	6.99215×10^{-07}
C_{Ca2}	L-type Ca^{2+} channel closed state mode Ca	6.71989×10^{-11}
C_{Ca3}	L-type Ca^{2+} channel closed state mode Ca	2.87031×10^{-15}
C_{Ca4}	L-type Ca^{2+} channel closed state mode Ca	4.59752×10^{-20}
O_{Ca}	L-type Ca^{2+} channel conducting state mode Ca	0.0
y	I_{Ca} inactivation gate	0.998983
$[LTRPNCa]$	concentration Ca^{2+} bound low affinity troponin binding sites	$6.349973\ \mu M$
$[HTRPNCa]$	concentration Ca^{2+} bound high affinity troponin binding sites	$135.9813\ \mu M$