NUMERICAL ANALYSIS OF INFLUENCE OF CONVECTION PARAMETER AND REACTION PARAMETER ON DRUG DIFFUSION THROUGH A STENT

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Abstract:

The diffusion of drug through a stent is analyzed with a convection parameter and drug reaction parameter using diffusion equation in cylindrical coordinates. . Effective drug delivery depends on the optimum design of the stent .Using cylindrical coordinates the results indicate more realistic conditions in drug delivery. Convection parameter and drug reaction parameter significantly influence drug diffusion. Hence by adjusting these parameters drug diffusion can be controlled.

Key words: diffusion ,convection parameter, reaction parameter.

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Introduction:

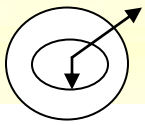
Stents are expandable metallic prosthesis implanted into the arterial wall .The stent provides mechanical support during the healing process and assists in keeping artery open. It is coated with a therapeutic drug. Once the stent is inserted into an artery, drug starts diffusing through the wall. The stent procedures show that the magnitude of the stresses and the volume of the material stressed depends on the stent design. In literature [1-5] different models of drug diffusion process has been analyzed.

Introduction of stent locally increases the curvature of artery resulting in low and high shear stress regions near stent edges which can cause restenosis. Since shape of the stent is is responsible for causing restenosis, the possible solution can be deforming the stent to make it fit the curvature of artery.

The present work studies the influence of convective parameter and drug reaction rate using diffusion equation in cylindrical coordinates . The equation is solved numerically .The solution indicates drug concentration at different distances in the wall at different time intervals. Hence the design of the stent is important for sustained drug delivery without restenosis.

Mathematical analysis:

Geometric model is a concentric circle as shown below with a stent near arterial wall. Rin is the inner radius and Ro is the outer radius. L1 is the stent thickness and L2 the artery wall thickness.



Rin =Ro –L1 – L2

The following assumptions are made in the analysis:

i) As the empty space in artery is larger than the thickness of stent , the stent and wall are considered to be two parts of a rectangular slab.

ii) The diffusivities of stent and wall are constant.

iii) The drug diffuses only in one direction

iv) The outer edge of wall is impermeable to the drug.

v) There are no sources and physical properties are constant.

Differential equation of the problem is

$(1/r)\frac{\partial}{\partial r}\left(r\frac{\partial c}{\partial r}\right) - \delta\left(\frac{\partial c}{\partial r}\right) - \beta c = 1/D(\frac{\partial c}{\partial t})$, D is drug diffusion parameter ,δ is convection parameter and β is a drug reaction parameter .

Initial condition

c(x,0)=0 , initially drug concentration is zero.

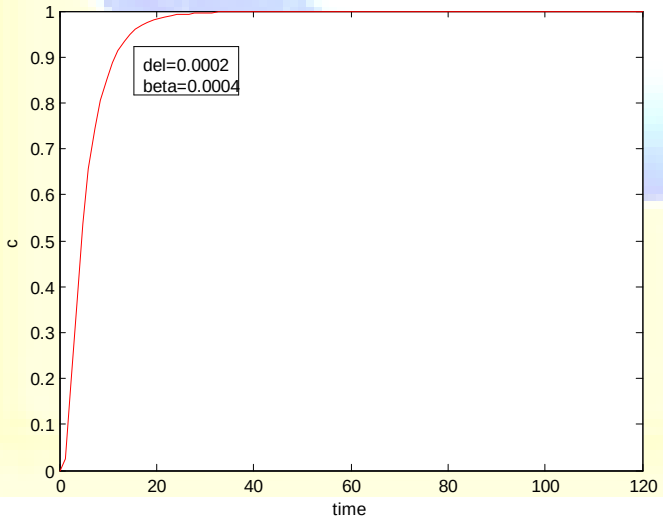
Boundary conditions

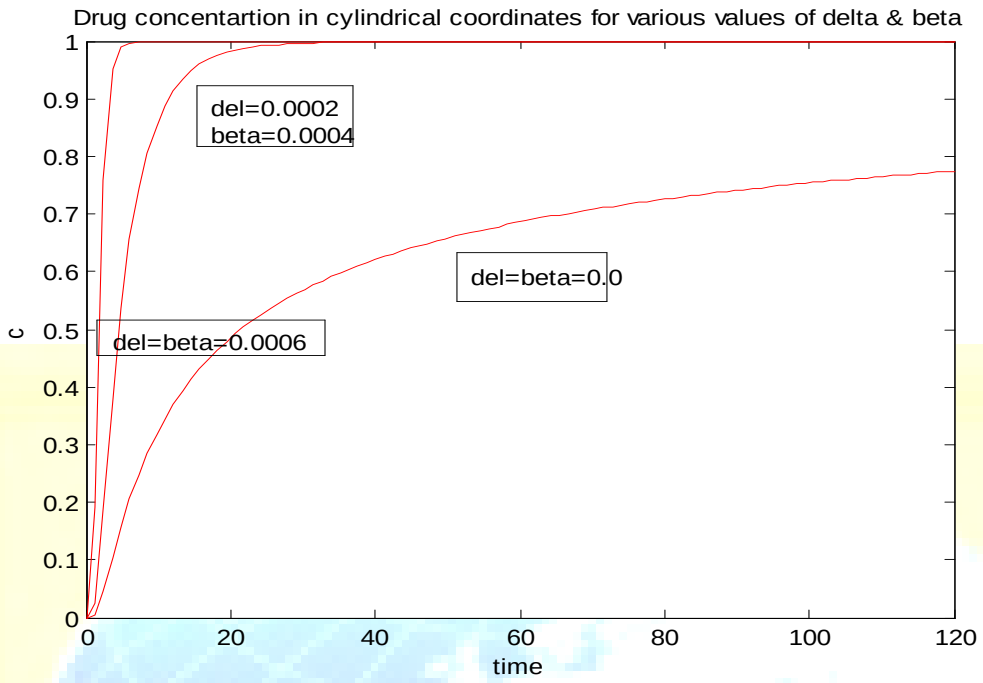
$c(r_1\ t) = c_{max}$

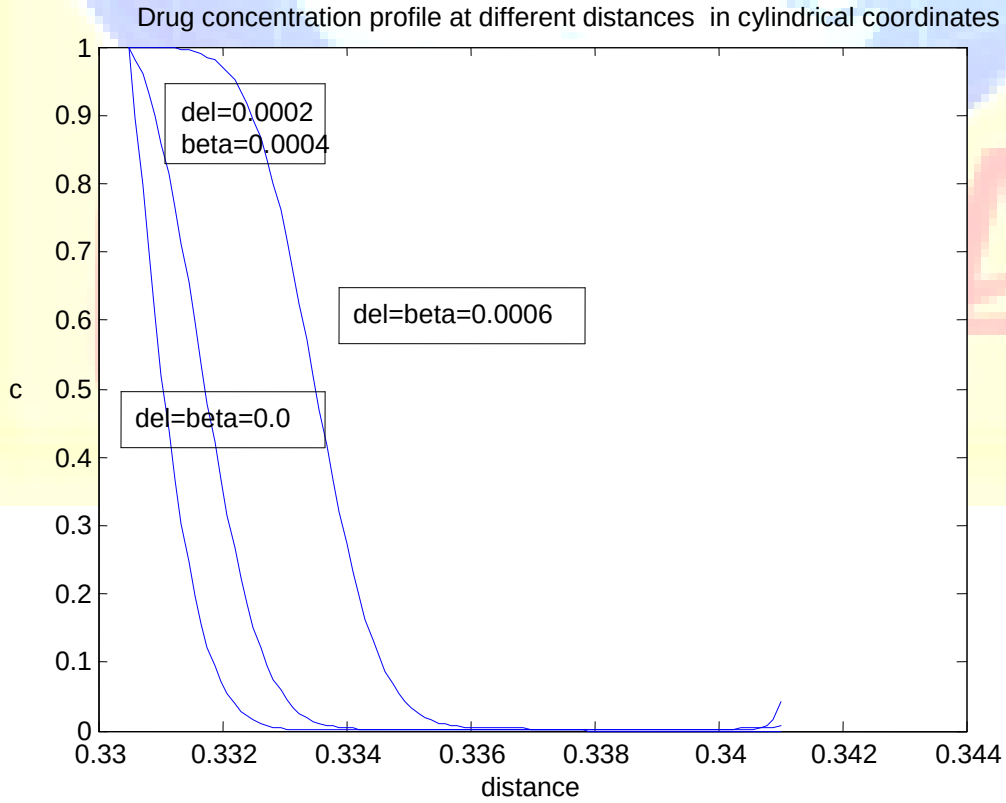
$(dc/dy)(r_2, t)=0$

Applying the boundary conditions the diffusion equation is solved for various values of β and δ . The solutions are plotted and analyzed.

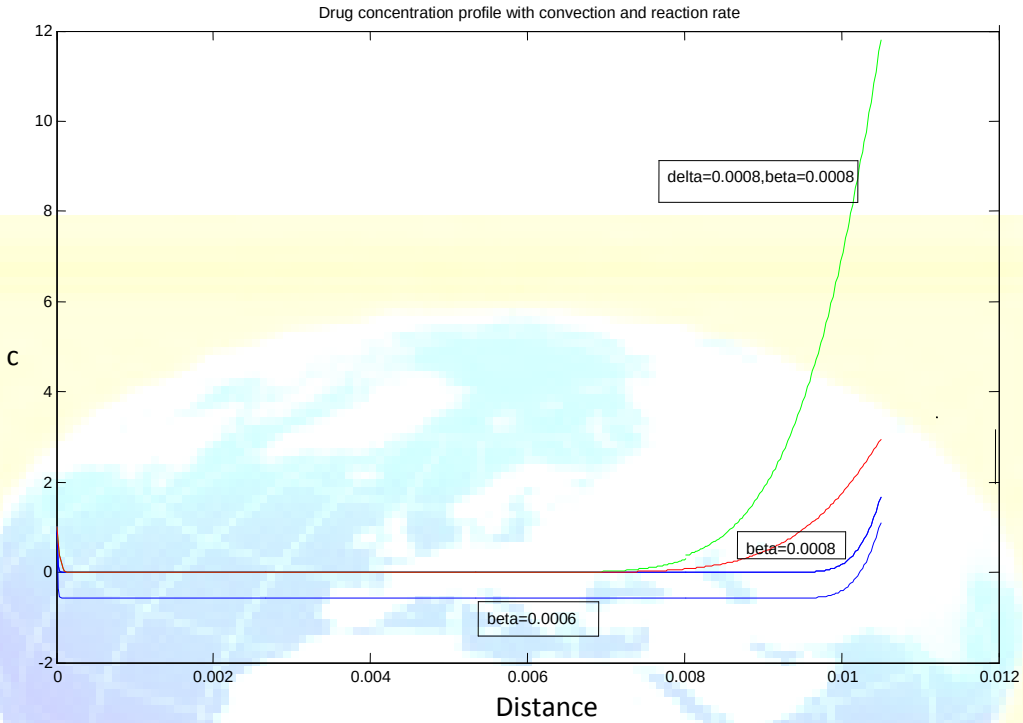
Drug concentration at various time intervals in cylindrical coordinates

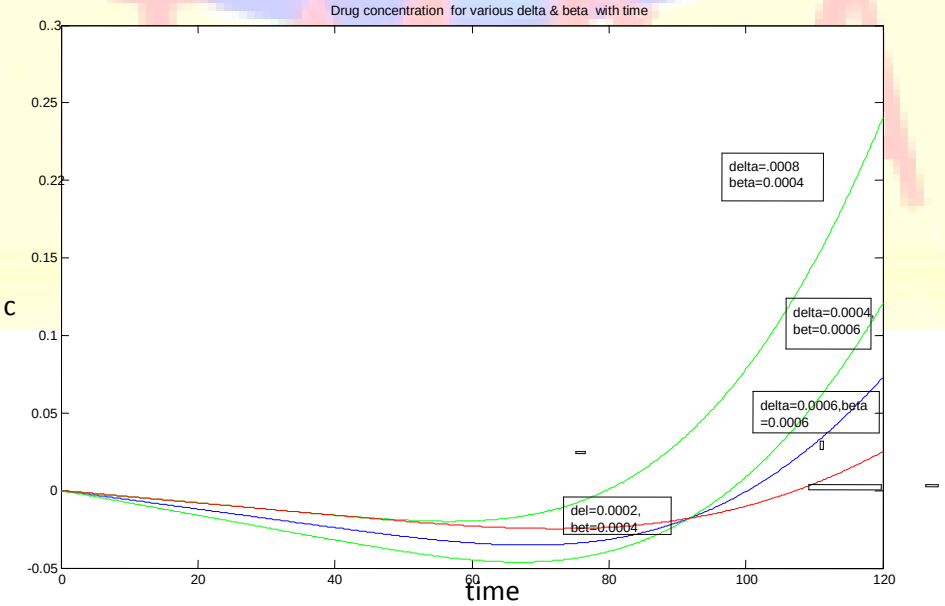


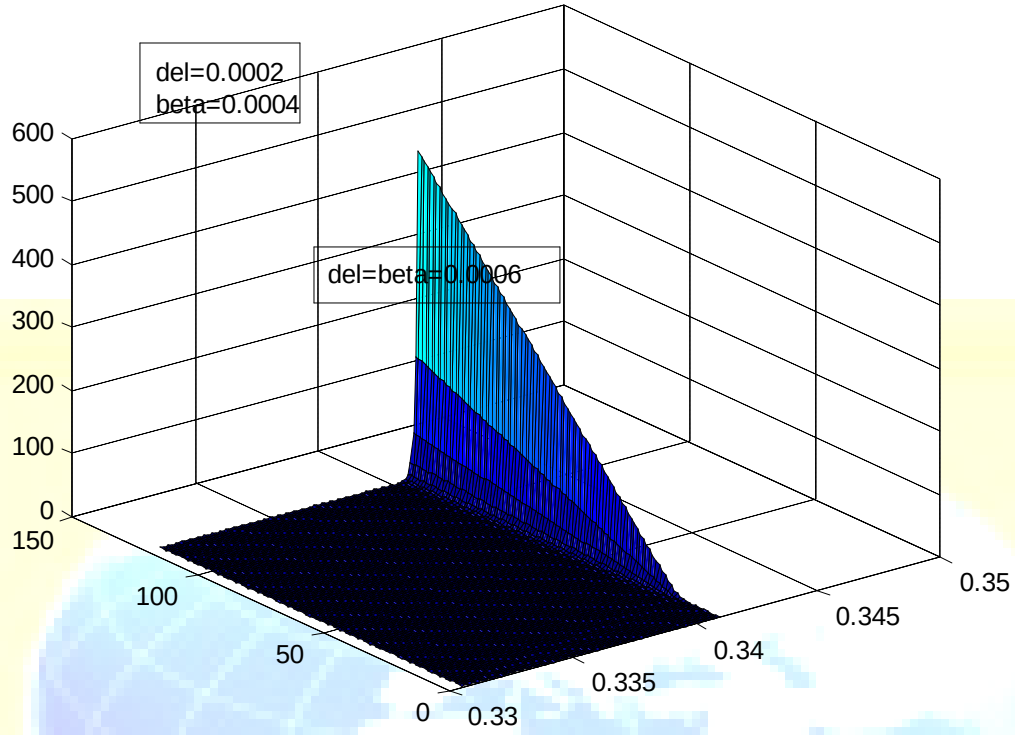

Drug concentartion in cylindrical coordinates for various values of delta & beta
del=0.0002
beta=0.0004
del=beta=0.0006
del=beta=0.0
c
time
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
20
40
60
80
100
120


Drug concentration profile at different distances in cylindrical coordinates
del=0.0002
beta=0.0004
del=beta=0.0006
del=beta=0.0
c
distance
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.33
0.332
0.334
0.336
0.338
0.34
0.342
0.344

Drug concentration at various distances for different δ and β in Cartesian coordinates







Surface plot of drug concentration

Results and conclusions

The figures illustrate that for Cylindrical coordinates in the absence of convective and reactive parameters, the drug concentration slowly drops after a certain distance from the stent wall. The process is more gradual as the values of convection and reaction parameter increase. The increase of concentration with time is more prominent in cylindrical coordinates. In Cartesian coordinates after certain interval of time the concentration of drug rises from the middle of the wall.

The plots for cylindrical coordinates indicate more realistic drug delivery system.

In the presence of beta and delta the concentration increases with time gradually and approaches maximum value. The variation of concentration with respect to time intervals is almost similar. This clearly indicates that by adjusting beta and delta the drug diffusion can be controlled.

In the above analysis the parameters δ and β are arbitrary which is not clinically valid.

References

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