Supplemental details: Theory, models and Python code

Appendix 1: Rapid equilibration between air-saturated water surrounding newly cavitated vessels

(1) Final equilibrium of gas pressure

Henry's law states that the concentration C_G ($mol \cdot L^{-1}$) of a gas species 'G' dissolved in water is in equilibrium with the partial pressure P_G^* of the gas species in air.

$$C_G = K_G P_G^* \tag{A1.1}$$

, where K_G ($mol \cdot L^{-1} \cdot atm^{-1}$) is the Henry's law constant.

If this is dissolved in a finite volume of solution, *(1-α)V*, then the number of moles of solute n_s in solution is

$$n_s = (1-\alpha)VC_G = (1-\alpha)VK_G P_G^* \tag{A1.2}$$

The two main gases in Eq. A1.2 are O_2 and N_2 with K_G values of 1.3×10^{-3} and 8.1×10^{-4} respectively and the partial pressure of O_2 and N_2 in air are 0.21 and 0.78 atm. If a fraction, α, of volume V is embolized and no additional air is added to the system then n_s moles of gas will be divided into n_1 moles of gas in the cavitated volume and n_2 moles in the water such that $n_s = n_1 + n_2$.

If P_G is the partial pressure of gas in the cavitated volume (αV) then the ideal gas law can be used to yield

$$n_1 = \frac{\alpha V P_G}{RT} \tag{A1.3}$$

, where RT = the gas constant times Kelvin temperature, and the number of moles in the liquid will be given by

$$n_2 = (1-\alpha)VK_G P_G \tag{A1.4}$$

Equating Eq. A1.2 to A1.3 + A1.4 and solving for P_G yields Eq. 1 in the introduction.

$$P_G = \frac{(1-\alpha)K_G P_G^*}{\alpha/_{RT} + (1-\alpha)K_G} \tag{A1.5}$$

The atmosphere consists of about 78% nitrogen and 21% oxygen, hence the final equilibrium bubble pressure should be the sum of the equilibrium pressure of nitrogen, the equilibrium pressure of oxygen and a full vapor pressure, which is a function of temperature (3.2 kPa at 298K).

(2) Diffusion time (cylindrical diffusion from bulk water)

The tempo of approach to equilibrium Eq. A1.5 can be computed by Fick's Law, which indicates that the radial diffusion rate of the gas species 'G' is proportional to the concentration gradient were diffusion occurs:

$$J_G = 2\pi D_G \cdot \frac{C_2 - C_1}{ln(b/a)} \quad \text{(A1.6)}$$

, Eq. A1.6 describes the diffusion in a unit length of cylinder where J_G is the diffusion rate in mol·s^{-1} per m of cylinder and D_G is the diffusion coefficient of gas; Eq. A1.6 describes the diffusion in a cylinder, where C_2 and C_1 are the concentration at the cylindrical surfaces with radius *b* and *a*, respectively (Crank, 1975).

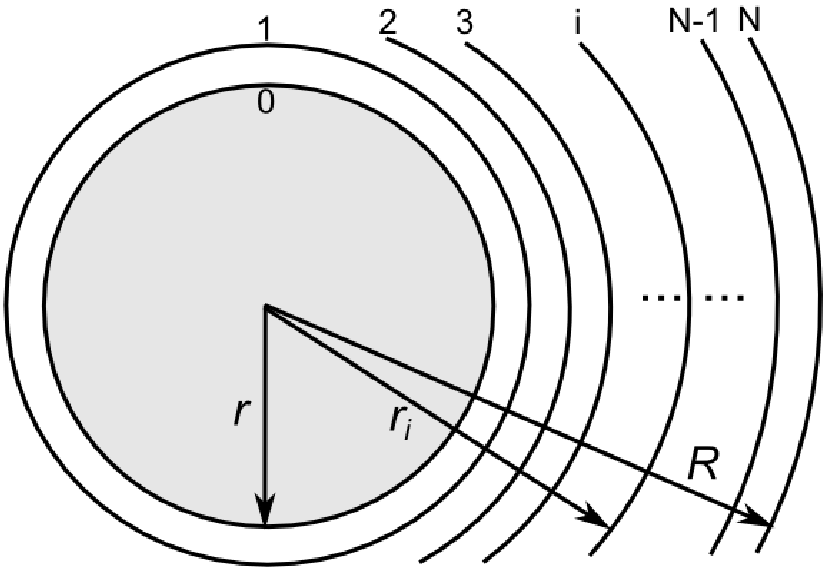

Figure S1. Model of cylindrical diffusion in stem. *R* and *r* are the radius of water (R = maximum radius) surrounding the vessel (r = vessel radius) , where r_i is the external radius of the *i*th layer of the N layers.

The cylinder was divided into N layers, each of which has a thickness of $\Delta x = (R - r)/N$. The boundaries of the *i*th layer of water $[r_{i-1}, r_i]$ are $[r + (i-1)\Delta x, r + i\Delta x]$; the distance of half volume site of the layer to the center of the vessel, x_i, is $\sqrt{(r_{i-1}^2 + r_i^2)/2}$. At a time interval Δt, the gas diffusion rate in mol s^{-1} that diffuses out from the ith layer to i-1^{th} layer will be:

$$\Delta n_i = 2\pi D_G \cdot \frac{C_{G,i} - C_{G,i-1}}{ln(x_i/x_{i-1})} \cdot L \cdot \Delta t \tag{A1.7a}$$

, where $C_{G,i}$ is the gas concentration of gas species 'G' in ith layer, which can be computed by Eq. A1.1, and $C_{G,0}$ is the equilibrium gas concentration in the cavitated vessel and L is an arbitrary length of the cylinder were diffusion occurs. Eq. A1.7 is used to compute the stem increase in dissolved gas concentration in the i^{th} cylindrical annulus in Fig. S1. The concentration change at ith layer would be $(\Delta n_{i+1} - \Delta n_i)/V_i$, where $V_i = 2\pi(r_i^2 - r_{i-1}^2)L$ so when this equation is substituted into A1.7 the value of L cancels out as does the 2π. So the equation for the increase in concentration in time step Δt is:

$$\Delta C_{G,i} = \frac{D_G \Delta t}{(r_i^2 - r_{i-1}^2)} \cdot [\frac{C_{G,i+1} - C_{G,i}}{\ln(x_{i+1}/x_i)} - \frac{C_{G,i} - C_{G,i-1}}{\ln(x_i/x_{i-1})}] \tag{A1.7b}$$

For initial condition at time 0 it is assumed that the cavitated vessel is filled with water vapor and the gases that were originally in the cavitated vessel before cavitation event happen (1.2 kPa N_2 and 0.6 kPa O_2). Therefore the gas pressure can be estimated by accumulating gas moles:

$$P_{G,t} = P_{G,t-\Delta t} + \frac{\Delta n_{1,t} RT}{2\pi r L} \tag{A1.8}$$

, where P_t and $P_{t-\Delta t}$ represent the gas pressure of gas species 'G' at time t and $t - \Delta t$ respectively, $\Delta n_{i,t}$ is the gas moles exchange in a time interval Δt at the time t.

The air pressure in vessels results from the combined diffusion of O_2 and N_2 which have different diffusion coefficients. Using an average vessel radius at 20 μm, the half time (T_{50}) and 99% equilibrium time (T_{99}) can be calculated and is shown in Fig. S2A, hence we can conclude that the initial bubble pressure can be reached in a short period of time.

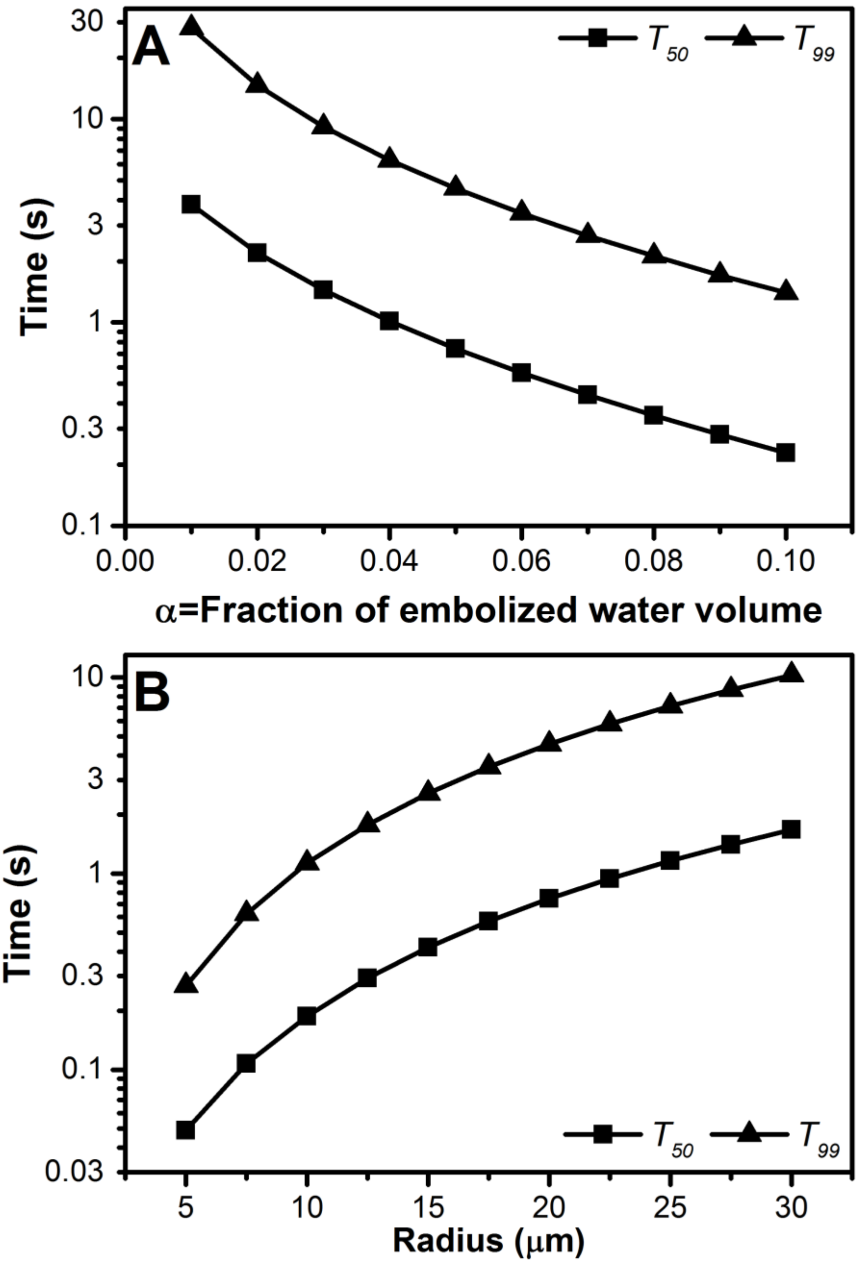

Figure S2. Relationship between α/radius and the half time and 99% equilibrium time. T_{50} and T_{99} refer to the half time (solid square) and 99% equilibrium time (solid triangle), respectively. Panel A: half time and 99% equilibrium time of the vessel with diameter of 20 μm when α range from 0.01 to 0.10. And in panel A α represents the fraction of embolized water volume in the stem. Panel B: half time and 99% equilibrium time of the vessel with diameter range from 5 to 30 μm when α is 0.05.

(3) Mass flow from the biggest pit pore

The following calculations demonstrate that mass flow of air through the biggest pit pore that seeds cavitation is very slow. According to the air-seeding hypothesis (Cochard et al., 1992; Sperry et al., 1996), an air bubble is pulled though the largest pit membrane pore connecting an embolized vessel to water-filled vessel. In this calculation let us assume the pore length, L, is 1 μm and the pore diameter, D, is 14.4 nm. A pore diameter this size would seed a cavitation at a tension of 2 MPa if the contact angle of the air-water interface with the pore wall is 0° and at lesser tension if the contact angle is >0°. This calculation assumes the pore remains filled with air and that pneumatic flow of air occurs indefinitely driven by the pressure difference between one vessel filled with air at atmospheric pressure to a recently cavitated vessel initially at 0 pressure.

Poiseuille's law for pneumatic flow is:

$$F_x = \frac{\pi \rho}{128\eta} \cdot D^4 \cdot \frac{dP_x}{dL} \qquad \text{(A1.9)}$$

, where F_x is the mass flow rate ($Kg \cdot s^{-1}$), ρ is the density of air, η is the viscosity of air (which is nearly constant when P_x < 500 kPa). According to Cohen et al. (2003), the air conductivity can be computed by $C = {QLP}/{A\Delta P\bar{P}}$, where Q is the volume flow rate ($m^3 \cdot s^{-1}$), L is the length of a pipe, A is the cross-section area of the pipe, P is the pressure where Q is measured, ΔP is the pressure difference across the pipe and $\bar{P}$ is the average pressure which equals to the mean of pressures at the two ends of the pipe (P_{in} and P_{out} below). So the atmospheric volume flow rate $F_{V,x}$ will be:

$$F_{V,x} = \frac{\pi D^4}{256\eta P_{baro} L} \cdot (P_{out}^2 - P_{in}^2) \qquad \text{(A1.10)}$$

And the maximum flow rate $F_{v,max}$ will be the flow rate when P_{out} is P_{baro} and P_{in} is 0. And the volume of the vessel is $V_V = 0.25 \cdot \pi D_v^2 \cdot L_v$, where D_v and L_v are the diameter and length of the vessel. The average volumes of vessel lumen are 1.54E-11 m^3 (*Acer mono*) and 5.94E-11 m^3 (*Populus 84K*), and the maximum volume flow rate (at atmospheric pressure) are 2.89E-17 $m^3 \cdot s^{-1}$ for both species on the assumption of same pit pore size. So the half time for an vacuum-filled vessel to obtain a bubble pressure about 50 kPa from the biggest pit pore will be $T_{half} = ln2 \cdot V_{vessel}/F_{V,max}$. And the T_{half} for an *Acer mono* vessel is about 3.1 days and T_{half} for a *Populus 84K* vessel is about 11.9 days.

Appendix 2: The Hydraulic Recovery Model: a model for estimating bubble pressure in vessels from measurements of stem k_h versus decreasing T_c in a cavitron.

The case of bubble pressure equilibrium in a vessel without pressure gradient has been discussed in Eq. 2 to 6 in the main paper. Below we discuss how the situation changes when there is a pressure gradient. The primary problem is to arrive at computational code that can transform Fig. 2 (the conductivity of a single vessel without a pressure gradient) to Fig 3 (the conductivity of many vessels in a stem segment in an environment with a quadratic pressure gradients), and also the case of linear positive pressure gradient. Linear pressure gradients arise when a conductivity apparatus is used in conjunction with a Sperry rotor whereas quadratic pressure gradients arise when measuring conductivity in a spinning Cochard rotor.

Once a computational algorithm is achieved for getting a stem segment conductivity, k_h, at any given initial bubble pressure (P_b^*) assigned at a high T_c values, the next step is use a curve fitting algorithm with root mean square error (E_{rms}) calculations to arrive at the value of P_b^* that best fits (minimizes E_{rms}) experimental data of k_h versus T_c for all the lower values of T_c during an experiment like those shown in Figs. 7 and 8.

(1) Pressure equilibrium between water and air in a single vessel with superimposed pressure gradient

In a centrifuge, there can be a static pressure gradient without flow of water wherein the most negative pressure occurs at the axis of rotation, and the pressure falls as a quadratic function of distance from the center ($P_w = \frac{x^2-R^2}{R^2} \cdot T_c + P_{baro}$, where x is the distance to the rotation axis). The centrifugal force will push the air bubble to the rotation axis hence the water will flow into the distal end of the vessel when $P_w + P_c > P_b$. In a conductivity apparatus (gravity flow system or flow meter), the water pressure will decrease linearly with distance in a stem and the bubble will tend to be oriented with the bubble at the low-pressure end of the vessel. However bubbles can ‘stick’ in small pipes by a process similar to the static coefficient of friction so the bubble could be anywhere in the vessel although for simplicity it is illustrated at the low pressure end of the vessel.

In an embolized vessel that is filled with an air bubble at a pressure of P_b^* under high tension in centrifuge, the bubble will collapse when the tension is decreased and the pressure equilibrium is achieved as shown in Fig. S3, where the meaning of R_{dv} and L_w is defined. At any given pressure gradient, the water and bubble lengths (or volumes) in the cavitated vessel finally equilibrate. The water pressure can be computed by a quadratic function in Cavitron system and from a linear function in a conductivity apparatus; the bubble pressure can be obtained by applying the ideal gas law as in Eq. 2. Eq. A2.2a gives the linear pressure gradient in a conductivity apparatus, and Eq. A2.2b gives the quadratic pressure gradient in a cavitron.

$$P_w = P_0 - \lambda L_w \tag{A2.2a}$$

$$P_w = P_{baro} + \left(\frac{(R_{dv} - L_w)^2}{R^2} - 1\right) \cdot T_C \tag{A2.2b}$$

, where λ is the coefficient of the pressure gradient, R is the maximum distance from the water level to the axis of rotation, P_w is the water pressure at the air/water interface at final equilibrium. The air bubble in the vessels are compressed hence the bubble pressure at final equilibrium P_b can be derived by the ideal gas law:

$$P_b = \frac{L_v}{L_v - L_w} \cdot P_b^* \tag{A2.3a}$$

. However, we have to take the air re-dissolved into the surrounding water as discussed in the main body. The equilibrium bubble pressure should be:

$$P_b = \frac{(1-\alpha) \cdot K_A + \alpha/RT}{(1 - \alpha + \alpha \cdot L_w/L_v) \cdot K_A + \alpha \cdot L_b/L_v\,/RT} \cdot P_b^* \tag{A2.3b}$$

where K_A is the Henry's Law constant for air and RT is the gas constant times Kelvin temperature. Therefore the final equilibrium in two systems can be given by:

$$P_0 - \lambda L_w + P_C = P_b \tag{A2.4a}$$

$$P_{baro} + \left(\frac{(R_{dv} - L_w)^2}{R^2} - 1\right) \cdot T_C + P_C = P_b \tag{A2.4b}$$

, where P_C is the capillary pressure computed by Eq. 3a. Here Eq. A2.4a and A2.4b show the equilibrium of a vessel in Flow Meter system and Cavitron system, respectively.

Both the water pressure and bubble pressure are functions of L_w, hence we can solve the functions to get the exact value of L_w. Newton iteration (details can be found on Wikipedia) is used to solve Eq. A2.4a and A2.4b to get the L_w in any given vessel location in a conductivity apparatus or centrifuge by assuming initial water length $L_{w,0} = 0$ and a function of $f(L_w) = P_w - P_b$ at the beginning and then:

$$L_{w,i} = L_{w,i-1} + f(L_{w,i-1})/f'(L_{w,i-1}) \quad \text{(A2.5)}$$

, where $L_{w,i}$ and $L_{w,i-1}$ are the length of water at ith iteration, and L_w can be gained when $L_{w,i} = L_{w,i-1}$. When pressure gradient $\lambda = 0$ and $P_0 = P_{baro}$ in a conductivity apparatus, L_w can be calculated by Eq. A2.4b with the value of $T_C = 0$, and this is how the Sperry PLC is simulated in Table I in the main body. Therefore, with Eq. A2.4 we are able to compute any pressure equilibrium of a vessel at any vessel that begin at a known slice that is R_{dv} far from the rotation axis, and hence to calculate the resistance of a cavitated vessel by Eq. 5.

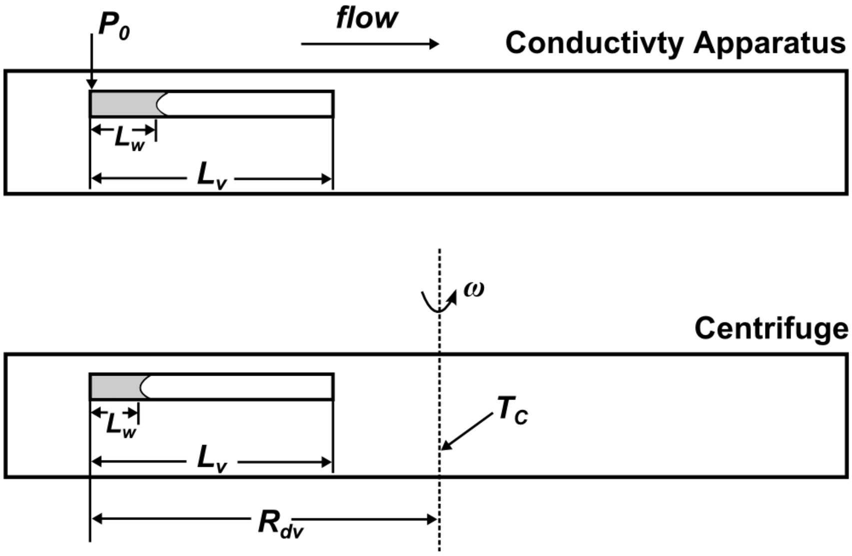

Figure S3. Model of water/air interface equilibrium in a single vessel. The upper panel shows equilibrium of a vessel in a stem connected to a conductivity apparatus while the lower panel shows equilibrium of vessel in a stem spun in a centrifuge. L_w and L_v represent the length of water and vessel, respectively. In the upper panel, P_0 is the water pressure at the upstream end of the vessel, and the pressure difference gradient is λ in $kPa{\cdot}m^{-1}$; and the water finally equilibrates with bubble as in Eq. A2.4a. In the lower panel, the central tension of the stem is T_C from angular speed ω, and the distance between the distal end of the vessel and the axis of rotation is R_{dv}; and water equilibrates with bubble as in Eq. A2.4b.

(2) Random vessel distribution and different equilibrium types

Vessels that are located in different places have different water pressure at the air/water interface and different bubble-length, so they have different final pressure equilibriums. Vessels are randomly distributed in stem such that any cross-section has the same possibility of vessel ends, vessel length distribution and vessel diameter. To make it simple, average vessel length and average vessel diameter were used to build the model instead of vessel-length distributions and vessel-diameter distributions.

As discussed above, in those vessels off the axis, bubbles are pushed towards the center because of the centrifugal force; but in those vessels that extend across the axis, water may enter from both ends and force bubble aggregate in the center as shown in Fig. S4. Air bubbles cannot exist in the sections of the stem immersed in water filled cuvettes (region a and e in Fig. S4). In our model the stem is divided into 5 parts: a, b, c, d and e as shown in Fig. S4; where a & e are immersed in water, c is the central region with length $2L_v$, and b & d are the remaining parts. When equilibriums are obtained in a Cavitron system, different computational algorithms apply based on different regions because of the vessel distribution. However, situation is simpler when segments are measured in a conductivity apparatus since bubbles tend to be pushed to the low-pressure ends, and hence Eq. A2.4a applies to the whole embolized segment.

In the Cavitron system, (1) in regions a and e, no air-seeding embolism can develop; (2) in regions b and d, equilibrium in normal type vessel can be given by Eq. A2.4b while end type vessel can be assumed as a normal type vessel with a shorter vessel length; (3) in region c, vessels can obtain equilibrium from one end just like the vessels in regions b/d, like vessel C_3 in Fig. S4; and can obtain equilibriums from both ends like vessels C_1 and C_2 in Fig. S4, and in this case the bubble length in these vessels is same as vessels that are symmetrically bisected by the rotation axis as vessel C_1 in Fig. S4. And the vessels like C_1 can be treated as two normal type vessels with length of $L_v/2$.

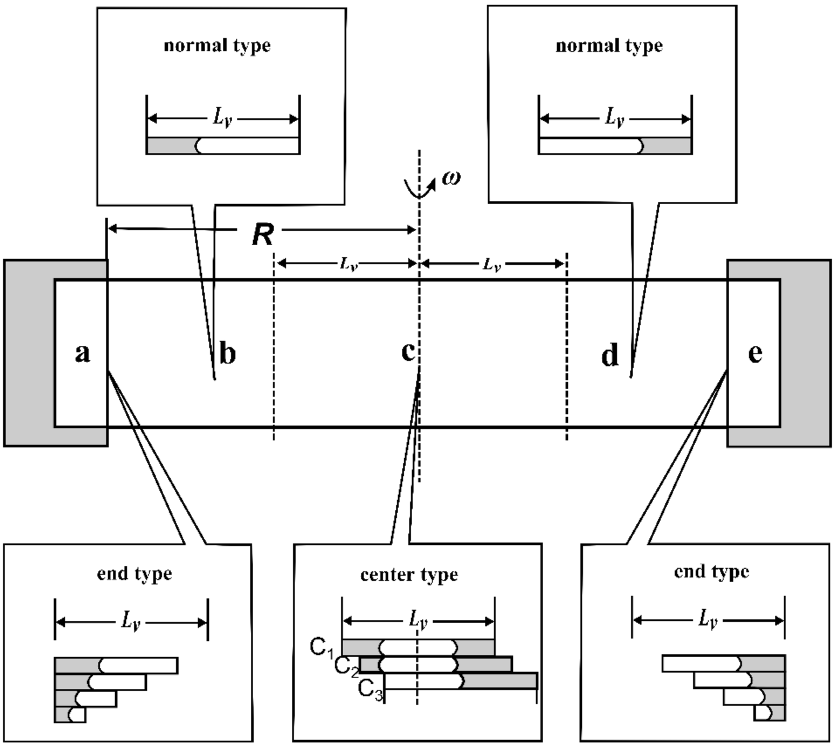

Figure S4 Model of stem divided into 5 regions and three types of cross-section. Five regions (a, b, c, d and e) are divided by the location and stature of vessels as described in Appendix 2.2. Three types of vessels (end, normal and center type) are defined based on the vessel location in any given slice. End type vessels are those that are open to the a/e boundaries, normal type vessels are those that locate between a/e boundaries and rotation axis, and center type vessels are those that cross the center.

(3) Stem model: adding up the resistances

Resistance of stem could be computed as $R_S=\sum R_{dx}\, dx$, where R_{dx} is the resistance of a dx-thick cross-section from the stem. To make it easy to understand, we use the average hydraulic recovery ratio of all the embolized vessels that pass through the slice to represent the hydraulic recovery ratio in the slice: $k = \sum k_i/N$, where k_i is the hydraulic recovery ratio of the ith vessel and N is the total number of vessels. So vessels are divided into three different type: end, normal and center types as described in Fig. S4.

Therefore, when equilibrium is obtained in end type vessels, the embolized vessel will recover its conductance by a ratio of $k = \frac{2 l_w l_v}{l_w^2 + l_v^2}$ (which follows from Eq. 5 in the main body), and here $l_v < L_v$ and l_w can be computed by Eq. A2.5. When equilibrium is obtained in normal type vessel, embolized vessel recover its conductance by a ratio of $k = \frac{2l_w l_v}{l_w^2 + l_v^2}$, and here l_v is the average vessel length L_v and l_w is computed by Eq. A2.5. In those center type vessels where equilibrium can only occur from one end, embolized vessels recover conductance by the ratio of $k = \frac{2l_w l_v}{l_w^2 + l_v^2}$, here l_v is the average vessel length L_v and l_w is computed by Eq. A2.5. And in these center type vessels where equilibrium can occur from both ends, embolized vessels recover conductance by a ratio of $k = \frac{2l_w l_v}{l_w^2 + l_v^2}$, and here l_v should be $L_v/2$ and l_w should be computed by using $L_v/2$ as vessel length as described above. When equilibrium occurs from both ends in the vessels that are a little off the axis like vessel C_2, we can find that the length of bubble should be the same hence the resistance of the vessel should be the same with that of C_1, where the whole-length vessels behave like two vessels with length of $L_v/2$ that behave like normal type vessels that locate in b/d region, therefore the pressure equilibrium of a half-length vessel was used to represent the final equilibrium in center type vessels where equilibrium establishes from both ends.

In the slices in b/d, some of the vessels are open to the boundaries of a/e hence partial length vessels are used to compute hydraulic recovery ratio, together with the full length vessels to compute the average *k*. In the slices in c, some of the vessels are open to the center, hence equilibrium is able to form in two ends in which case can be treated as vessel C_1 in Fig. S4; and those vessels that are off the center and those that cross the center but with equilibrium only at one end can be treated as normal type vessels and share the same equation to compute *k*. And in this way, every embolized vessel that cross a given slice can be computed and then average *k* can be derived.

In a partly embolized stem, only $\varepsilon = n/N$ of the vessels out of a cross-section are cavitated or embolized (*n* is the number of cavitated/embolized vessels and *N* is the total number of all the vessels), and it was assumed that all vessels are of the same diameter and length. When water/air interfaces equilibrate with bubbles, the fraction of non-embolized vessels (1-ε) are fully conductive while the fraction of embolized vessels (ε) recover their conductivity by a ratio of *k*, and hence the conductivity of the slice is $[(1-\varepsilon) + k\varepsilon] \cdot k_{h,0}$, where $k_{h,0}$ is the conductivity of the slice with no embolism; and the resistance of the cavitated vessels will drop as calculated from Eq. 5 and the resistance of the slice will be computed by:

$$R_{dx} = \frac{1}{(1-\varepsilon) + k\varepsilon} \cdot R_0 \tag{A2.6}$$

, where R_0 is the resistance of the *dx*-thick slice when stem is fully conductive. Here resistance rather than conductance is used because resistance can be added up directly in a series of slices.

With the description above, the resistance of every *dx*-thick could be computed to add up to the overall resistance of the stem by Eq. A2.6. We sacrifice some of the accuracy of the model output in order to simplify some of the calculations and save computational time which is currently about 20 minute per curve fitting. Future models are worth developing with fewer sacrifices.

After all the resistances of *dx*-thick slices are calculated and added up at a given tension, the total resistance of the stem is used to obtain the k_h of the whole stem under different tensions by:

$$R_S = \sum R_{dx} \tag{A2.7a}$$

$$k_h = \frac{R_{S,0}}{R_S} k_{max} \tag{A2.7b}$$

, where $R_{S,0}$ is the resistance of the fully conductive stem, and k_{max} is the maximum hydraulic conductivity of the stem.

PLC distribution in stems from centrifuges has been studied at slightly above atmospheric pressure (Cai et al., 2010), but how *PLC* is distributed in segments spinning in a rotor remains unknown because the bubble pressure of air in vessels in the experimental conditions of Cai et al. (2010) is unknown. In this paper the fraction of embolized vessels (ε) is assumed to be evenly distributed in stem between two reservoirs, hence we assigned the same ε values in sections b, c and d under high tension while a and e sections remain non-embolized (ε=0). In the second paper of this series other distributions are considered and used to check how much the hydraulic recovery curve could be influenced by different distributions of ε in stems spun in centrifuges.

In summary, the model assumes that (1) vessel length and vessel diameter were the same in every vessel in the stem, (2) bubble pressure was the same in every cavitated vessel under high tension, (3) embolized vessel fraction ($\varepsilon = n/N$) was evenly distributed in b, c and d parts, and (4) contact angle in vessels was assigned to 45º (π/4), which ranges from 42° to 55° (Zwieniecki and Holbrook, 2000). Based on these assumptions, the hydraulic recovery model is accomplished by: (1) calculated the resistance of a *dx*-thick slice, (2) added up the resistances of the stem, (3) computed hydraulic conductivity from resistances, and (4) calculate how hydraulic conductivity changes with decreasing tension.

The model was coded and run in Python(x,y) 2.7.5, the code can be found in the supplemental python script in Appendix 3.

Appendix 3: Python code of the Model

Note: The sentences after '#' are code descriptions, which will not run in python compiler. And to make it easy to read, we use a monospace font "Consolas" and landscape layout.

```
# range of central tension from 0.0 to 5.0 MPa
center_tension = []
tmptension = 0.0
while(tmptension <= 5.0):
    center_tension.append(tmptension)
    tmptension += 0.01

KCP_O = 1.30E-3 #mol.L-3.atm-1
KCP_N = 6.10E-4
KCP_A = 0.80*KCP_N + 0.2*KCP_O
RT = 298.0 * 0.0821 # atm.L.mol-1

def find_x(l,ct,bs):
    x = 0
    count = 0
    if (bs ** 2 / 0.127 ** 2 -1) * 1000 * ct + 100 + cp > BP:
        while 1:
            count = count + 1
            if(count >=20):
                x = l
                break
            fr = x / l
```

```
            fwt = 1.0 - center_PLC/100.0/10.0
            fbt = center_PLC/100.0/10.0
            fwe = fr*fbt + fwt
            fbe = fbt*(1.0-fr)
            funcKt = KCP_A*fwt + fbt/RT
            funcKe = KCP_A*fwe + fbe/RT
            EquilP = BP * funcKt/funcKe
            # judge here is Pw+Pc-Pb
            judge = ((abs(bs) - x) ** 2 / 0.127 ** 2 -1) * ct * 1000.0 + 100.0 + cp - EquilP
            # slope here is the slope of "judge" at x
            slope = - ct * 1000.0 / 0.127 ** 2 * 2.0 * (abs(bs) -x) + BP*funcKt/(funcKe**2) * (fbt/l*KCP_A - fbt/RT/l)
            # Newton Iteration
            x = x - judge / slope
            #print judge,slope,x
            if (abs(judge) < 0.0001):
                # To judge when to stop
                break
            # A Statement to avoid overflow
            if x >= l or x < 0:
                x = l/1.2
    return x
# A function to compute the resistance of the embolized vessels at any given slice
def drawf_PLC(ct,vl):
    # Begin the slice array from the distal end of region a by the thickness of 0.001 m
    site = -0.137
```

```
    dsite = 0.001
    # Stop after the last slice at 0.137 m
    while(site < 0.138):
        # The resistance of slices in a/e is constant R0, we use R0=1.0
        if(abs(site) > 0.127):
            NEWR.append(1.0)
            OLDR.append(1.0)
        # The resistance of slices of end and normal type
        elif(abs(site) >= vl):
            klist = []
            ith = 1
            while(ith <= 100):
                tmpml = ith*0.01*vl + 0.127-abs(site)
                if(tmpml > vl):
                    tmpml = vl
                    tmpbs = abs(site) - (vl - ith*0.01*vl)
                    tmpwl = find_x(tmpml,ct,tmpbs)
                    tmpki = 2.0*tmpml*tmpwl / (tmpml**2 + tmpwl**2)
                    klist.append(tmpki)
                else:
                    tmpwl = find_x(tmpml,ct,0.127)
                    tmpki = 2.0*tmpml*tmpwl / (tmpml**2 + tmpwl**2)
                    klist.append(tmpki)
                ith += 1
            kr = numpy.mean(klist)
            NRdx = 100.0 / ((100.0-center_PLC) + kr*center_PLC)
```

```
                ORdx = 100.0 / (100.0-center_PLC)
                NEWR.append(NRdx)
                OLDR.append(ORdx)
        # The resistance of slices in region c
        else:
            klist = []
            ith = 1
            while(ith <= 100):
                tmpml = vl
                tmpbs = max(abs(site)+vl-ith*0.01*vl,abs(abs(site)-ith*0.01*vl))
                tmpes = min(abs(site)+vl-ith*0.01*vl,abs(abs(site)-ith*0.01*vl))
                if(abs(tmpbs) < vl):
                    # A judgement use to judge whether the equilibrium establish from both ends
                    ljudge = vl / (2*tmpes) * BP
                    # Patm = 100.0, Tension in MPa
                    rjudge = cp + ((tmpes/0.127)**2 - 1.0)*ct*1000.0 + 100.0
                    if(ljudge >= rjudge):
                        # When the slice is normal type slice
                        tmpwl = find_x(vl,ct,tmpbs)
                        tmpki = 2.0*tmpml*tmpwl / (tmpml**2 + tmpwl**2)
                        klist.append(tmpki)
                    else:
                        # When the slice is center type slice
                        tmpwl = 2.0 * find_x(vl/2.0,ct,vl/2.0)
                        tmpki = 2.0*tmpml*tmpwl / (tmpml**2 + tmpwl**2)
                        klist.append(tmpki)
```

```
                    else:
                        tmpwl = find_x(vl,ct,tmpbs)
                        tmpki = 2.0*tmpml*tmpwl / (tmpml**2 + tmpwl**2)
                        klist.append(tmpki)
                    ith += 1
                kr = numpy.mean(klist)
                NRdx = 100.0 / ((100.0-center_PLC) + kr*center_PLC)
                ORdx = 100.0 / (100.0-center_PLC)
                NEWR.append(NRdx)
                OLDR.append(ORdx)
            site += dsite

# Main Body of the Code
# cp here is actually capillary pressure
# Here we use lists to store the values of each parameter
cps = [7.0,]
vessel_lengths = [0.04,]
filenames = ["./Test.txt",]
Kmaxs = [1.0E-4,]
cPLCs = [50.0,]
BPs = [50.0,]
# main part
for i in range(len(filenames)):
    # Assign the parameters!
    OLDR = []
    NEWR = []
```

```
    savefilename = filenames[i]
    kmax = Kmaxs[i]
    center_PLC = cPLCs[i]
    BP = BPs[i]
    cp = cps[i]
    vessel_length = vessel_lengths[i]
    savefile = open(savefilename,"w+")
    savefile.write("Tension\tKh\tPLC\n")
    # Here we give a limit to vessel length to avoid overflow
    if vessel_length < 0.127:
    #cycle through center tensions
        for tension in center_tension:
        # Clear OLDR,NEWR in each cycle
            OLDR = []
            NEWR = []
            # Compute the resistance in 275 slices
            drawf_PLC(tension,vessel_length)
            tmpkh = kmax * (274.0 / sum(NEWR))
            tmplc = 100.0 - 100.0*(274 / sum(NEWR))
            tmpstr = str(tension) + "\t" + str(tmpkh) + "\t" + str(tmplc)
            print tmpstr
            savefile.write(tmpstr + "\n")
    # Save the output results and close the file
    savefile.close()
```

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